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REPORT

SEWAGE SLUDGE DISPOSAL

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Preparation of this report took place prior to the reorganization of the Ontario Government in the Spring of 1972. As a result, many of the agencies referred to now have new titles. The Ontario Water Resources Commission and the Department of Energy and Resources Management have become part of the new Ministry of The Environment. The Department of Health is now the Ministry of Health, the Department of Municipal Affairs is now the Ministry of Treasury, Economics and Intergovernmental Affairs, the Department of Agriculture and Food is now the Ministry of Agriculture and Food, and the Department of Lands and Forests is now the Ministry of Natural Resources.

As a result of the Ontario Government reorganization many of the problems regarding jurisdiction over sludge disposal, outlined in Section 3.3.2 of this report have been eliminated.

R. M. Bell

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SEWAGE SLUDGE DISPOSAL

A Report by The Ministry of The Environment

Project Operations Branch

Prepared by: - Mr. R.M. Bell

November 1971

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ABSTRACT

Disposal of sludge from municipal sewage treatment plants is a costly and troublesome aspect of sewage treatment for the OWRC's Division of Plant Operations and other operating agencies in Ontario. It appears that the current situation will deteriorate further without major policy changes on the part of the OWRC. This paper is intended to summarize the experiences of the Division of Plant Operations and others, regarding the ultimate disposal of sludge, with the purpose of providing the groundwork for future OWRC policy in this regard.

It is recommended that the OWRC undertake measures, as soon as is practical, to remedy the jurisdictional conflict between the various Provincial bodies in the matter of sludge disposal. The OWRC should adopt a preference for the method of land application for sludge disposal. It is recommended that one of the conditions for acceptance of future nutrient removal processes be that they must not interfere with the ultimate disposal of the sludge generated at a treatment plant. The OWRC should ensure that the design of all new sewage treatment plants or of major extensions to existing ones, include the method of sludge disposal to be used. It is recommended that a public relations effort be undertaken to promote an understanding of the sludge disposal practises, among municipal officials, the agricultural community, and the general public. The OWRC should increase its efforts to control the disposal of sludge through direct supervision and by means of improved sludge hauling contracts. It is recommended that the OWRC in conjunction with the Department of Agriculture and Food, undertake research regarding the disposal of sludge by land application to determine desirable application rates and optimum disposal site characteristics and management procedures. It is suggested that there should be some experimentation with various methods of control over sludge disposal sites such as lease or purchase of these sites by the operating agency. Transportation of sludge by pipeline should be explored by construction of a short length of such a pipeline. Communication should be maintained with the Provincial bodies which regulate urban growth to make these bodies aware of the problems of disposal of sludge and other solid wastes from urban centres.

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1 INTRODUCTION

This paper deals with the disposal of solid wastes (sludge) generated in the primary and secondary clarifiers of municipal sewage treatment plants. This sludge is a portion of the solid matter in sewage and of the dissolved matter which has been converted to solid form through biological or chemical treatment. The paper is primarily concerned with the problems involved in the ultimate disposal of the sludge rather than the processing of this material prior to disposal.

At present, the OWRC's Division of Plant Operations operates some 59 municipal sewage plants in Ontario which require sludge disposal. The disposal of sludge from these plants as well as others outside the control of the Division of Plant Operations is becoming increasingly costly and difficult. It is the intention of this paper to summarize the experiences of the Division of Plant Operations and others in this field with the purpose of providing the groundwork for future OWRC policy in this matter.

There are three basic methods for disposing of sludge currently being practised. For the purpose of this report, these methods will be referred to as dumping, land application and incineration. The first two methods are the most widely practised in Ontario although there are incinerator installations in the large cities (e.g., Toronto and London). There are no OWRC operated plants employing incineration.

Section two of this report will attempt to provide a brief summary of current practices regarding ultimate disposal of sludge. Considerable emphasis has been placed on disposing of sludge by the method of land application. This is due to the belief that it is the method most applicable to Ontario circumstances. Section three deals with the sludge disposal practices at plants operated by the OWRC. Section four concerns future problems regarding sludge disposal which are anticipated in Ontario in the next few years. In section five, recommendations have been made for OWRC policy regarding sludge disposal.

2. SUMMARY OF CURRENT STUDY DISPOSAL METHODS

2.1 General

There are three basic methods for disposing of sludge from municipal sewage treatment plants; dumping, incineration, and land application. Dumping may be defined as depositing the sludge in such a way that its properties (with the possible exception of the volume it occupies) are not utilized. Also, dumping involves depositing the sludge with the intention of not removing it. Disposal of sludge by invineration involves heating of the sludge to the extent that the majority of the solids are oxidized and essentially all the water is evaporated. Disposal of sludge by land application involves distributing the sludge over the surface of land in such a way as to utilize some aspect of the soil fertilizing, conditioning and irrigating properties of the sludge, and in such a way as to enable the soil to assimilate the sludge without detriment.

The suitability of a particular sludge disposal method depends on a number of factors which can be summarized under the three headings; economic, ecological, and political. Ecological factors could be considered as long-term economic factors.

Economic factors include:

a) Volume of sludge to be disposed of.

b) Characteristics of the sludge (solids concentration, putrescence, nutrient content).

c) Geography of the area as it affects land application and dumping (land use, population density, soil characteristics, topography).

d) Climate of the area as it affects land application (precipitation, temperatures).

Ecological factors influencing the choice of disposal methods include:

a) Potential for pollution of air, water or soil, as it affects the hygiene of humans and all other forms of life.

b) Desirability of using valuable properties of the sludge.

c) Aesthetics.

Political factors include:

a) Local by-laws regulating land use and waste disposal.

b) Public relations with individuals and groups.

The three basic methods of disposal will be discussed individually in sections 2.2, 2.3, and 2.4 of this report. The aspect of transportation of sludge which may affect all the methods to some degree has been dealt with separately in section 2.5 of this report. Capital and operating costs for the three methods have also been discussed separately, in section 2.6 for ease of comparison.

2.2 Disposal by Dumping

2.2.1 Characteristics

Sites used for disposing of sludge by dumping have included sanitary landfill sites, open dumps, abandoned quarries and gravel pits, man-made or natural lagoons, subterranean cavities and the sea. At sanitary landfill sites and open dumps the sludge is generally disposed of along with other solid or liquid wastes from municipal and industrial sources. Transportation to dumping sites is generally by trucking but in the case of disposal at sea, barging and piping are also used. As the topic of transportation is applicable to other methods of sludge disposal, it will be dealt with separately in section 2.5 of this report.

Sludge disposed of by dumping should be well digested to reduce its putrescibility and pathogenic organism content. One or more of the various methods of dewatering may be employed to reduce the volume of sludge to be handled but this is a matter related primarily to the economics of sludge transportation.

2.2.2 Disadvantages

This method of disposal has three main drawbacks. Firstly, each disposal site has a limited lifetime (before it becomes filled to capacity). New locations (which are usually less and less desirable) must eventually be found if use of this method is to continue. This method adds to the already burgeoning problem of solid waste disposal, now estimated to be accumulating at the rate of 4 to 5 pounds per person per day in Canada and the United States. In areas of high population density, the availability of land is naturally at a premium. Also land used for the disposal of sludge by dumping, will be of little other use, as it generally cannot be built on or cultivated. It may, however, be reclaimed for recreational purposes after surface restoration.

Secondly, there is the potential for ground water and for surface water pollution from a large concentrated mass of sludge. The liquid which percolates into or onto the soil will be high in nutrient concentration and possibly pathogenic organisms depending on the degree of digestion and/or chemical treatment. While there is a scarcity of information dealing specifically with the dumping of sludge, the problems are somewhat analagous to those for municipal garbage. Leachate from a surface disposal site must be considered in the design and operation of the site.

Three design objectives proposed by Farolden and Hughes (19) for a sanitary landfill site are: a) to allow for predicted and acceptable migration of the contaminants from the site, b) to allow for migration and subsequent collection of the contaminants, and c) to retain and collect the leachate within the fill. Quasim and Burchinal (5) after studying leaching in sanitary landfills, concluded that deeper fills pose less of a pollution problem than do the shallower fills, which may leach the bulk of their pollution in a shorter time period thereby exceeding the dilution capacity of the moving ground waters. Noering, et/al (44) concluded that there was considerably less danger of contaminating ground water with deposits of garbage placed above ground water level rather than below. The W.P.C.F. (63) states that in designing sludge lagoons the possibility of pollution of ground water or nearby surface waters should be investigated thoroughly. In some cases sludge lagoons may have to be lined with plastic or rubber fabrics.

Another problem with sludge disposed by dumping is that the valuable properties of the sludge itself are wasted. The soil fertilizing and conditioning properties of sludge will be discussed further in this report in connection with disposal by land application (see section 2.4.3).

Problems with odours and insect breeding can occur but will not be important if proper digestion of the sludge and management of the dumping site is practised (63).

2.2.3 Advantages

Advantages of sludge disposal by dumping are threefold. The method can be relatively simple as there is minimum of manpower and facilities required. It can be used as a temporary procedure during peak load periods or when other disposal processes are out of service. The method is not seriously affected by local climatic conditions and can be used year round, thus eliminating the need for sludge storage at the plant.

2.3 Disposal by Incineration

2.3.1 Characteristics

Among the incineration processes currently in use are the multiple hearth furnace, rotary kiln, fluidized bed and atomized suspension technique. Wet air oxidation processes such as Zimmerman and Cedarquist processes, have not been included under the heading of incineration although there is oxidation of sludge solids with these processes. The total volume of sludge entering these processes is the same as that leaving and hence wet air oxidation is primarily a stabilizing and conditioning step (3). Sludge drying processes have like-wise been excluded from the incineration catagory because although there is stabilization of the sludge and an extensive reduction in water content, there

is little oxidation of solids. Hence sludge drying is primarily a stabilizing and dewatering step.

From the standpoint of economics, sludge disposal by incineration usually necessitates prior dewatering of the sludge. Dewatering is not prompted by transportation costs as in the case of disposal by dumping and land application, because incineration is generally carried out at the treatment plant site. Instead, dewatering is necessary to balance as much as possible, the heat required to evaporate the water and deodorize the gasses of combustion, with the heat available from the combustion, of the sludge solids.

Sludge dewatering may be accomplished by one or more of the conventional dewatering processes such as thickening tanks, vacuum filters, centrifuges and presses. When chemicals are used to condition sludge prior to dewatering, organic polyelectrolytes are preferable to lime and iron salts from the standpoint of reducing the quantity of residual ash (23), and also because polyelectrolytes have no direct effect on the heat balance of sludge combustion and maintain comparable costs (20), (25). For the atomized suspension technique, the desired sludge solids concentration is 8.0% to 11.0% (6) and hence dewatering in thickening tanks only may be possible. Recommended solids concentrations for most other incineration methods are in the order of 25% (6) and hence sludge thickening alone would be inadequate.

The principal end products of sludge incineration are water vapour, carbon dioxide, sulphur dioxide, nitrogen dioxide, and an inert ash which consists mainly of silicon dioxide (23), (6). Destruction of organic material is almost 100%, (6).

Digestion of sludge prior to incineration is undesirable as it reduces the thermal value of the sludge by about 50% (6) and thereby increases auxiliary fuel requirements. Because the volatile content of the sludge has such a significant effect on the operating cost, efficient degritting of the raw sewage entering the sewage plant will reduce operating costs (20).

2.3.2 Disadvantages

There are six main disadvantages to sludge disposal by incineration. First, incineration necessitates some dewatering of the sludge. Dewatering ususally necessitates treatment of the extracted filtrate, centrate, supernatant, etc., in the sewage treatment plant. This portion of the sludge contains considerable amounts of nitrogen and phosphorus and fine particulate matter. When this material is recycled back to the plant influent, and if the plant influent contains sufficient nutrients for the microbes in the subsequent biological processes as is generally the case in municipal sewage plants, then the nutrients from the sludge dewatering process will end up in the plant effluent. The importance of the added load varies with the wastewater treatment processes used (63), (8). For treatment plants designed to accomplish a high degree of overall solids removal, the recycling of filtrate or centrate solids back to the treatment plant processes may impose a significant added loading and could reduce the overall treatment plant efficiency. Dalton, et/al (3) reported a marked increase in effluent nitrogen concentration under such conditions. In addition to these process considerations, dewatering of sludge is a source of high capital and operating cost.

2.3.3 Advantages

The main advantage of sludge disposal by incineration is the extensive reduction in the volume of the sludge to be disposed of. Although volume reduction is not complete the costs of transporting and disposing of the remaining ash will be small relative to that for the unincinerated sludge. For instance, if a dewatered sludge with a solids concentration of 20% is incinerated, there would be approximately a 96% reduction in the volume of the sludge, assuming 70% of the dry solids are destroyed during incineration.

Secondly incineration eliminates the possible hygenic problems associated with the presence of pathogens in conventionally digested sludge (anaerobic or aerobic digestion). The high temperatures required for incineration and odour control, completely destroy all organisms in the sludge.

A third advantage of incineration can be the fact that it obviates the need for sludge digestion. When planning a new sewage treatment plant this will enable the designer to eliminate a source of high capital and operating costs.

Another advantage is that incineration is not subject to the climate of the area, enabling uninterrupted disposal and thus eliminateing the need for extensive sludge storage at the plant.

2.4 Disposal by Land Application

2.4.1 Characteristics

2.4.1.1 General

The use of sludge for its soil fertilizing, conditioning, and irrigating properties is not new. It is being applied to agricultural land used for crops and pasture (3), (2), (58), waste land damaged by such operations as strip mining or dumping of mine tailings, (3), (24), recreational areas such as golf courses and parks (2), (6), (3), and miscellaneous land such as roadsides, private gardens, lawns, etc.

Transporting the sludge from sewage plant to disposal site is generally accomplished by trucking or pumping. This aspect of sludge disposal is important from the economic standpoint, especially when large volumes of sludge are being disposed of, because the available disposal sites are usually remote from the sewage plant. As the topic of sludge transportation can have application to the other methods of sludge disposal, it will be dealt with separately in section 2.5 of this report.

The method chosen for applying sludge to the disposal site depends on several factors including the means by which the sludge is transported to the site, seasonal temperatures, the solids concentration of the sludge, the usage of the land and the volume of sludge to be disposed of. Methods that have been used include spraying or injecting from the back of a tank truck or manure spreader, ridge and furrow irrigation, and spray irrigation. There is much manure handling and spreading equipment presently being used by the agricultural community which would be suitable for applying sludge of all concentrations.

Second, the volume of sludge to be disposed of is greatly reduced but not completely. Although destruction of organic solids is almost complete, the weight of ash produced may average 30% of the weight of dry solids incinerated (6). Hence incineration still leaves part of the sludge to be disposed of. The ash is inert and will produce no disposal problems from the hygenic standpoint, but it is suitable only for dumping at sanitary landfill sites and hence some of the problems discussed earlier under disposal by dumping apply.

A third problem with incineration is that of air pollution. Since incineration is carried out at the sewage plant site, and the sewage plant is of necessity in or near the municipality it serves, the air pollution usually affects an area of high population density. Air pollution control equipment such as water scrubbers or centrifugal dust collectors which are a source of high capital and operating costs must be installed. Both scrubbers and centrifugal (cyclone) collectors remove 75 to 80% of the particulate matter in the exhaust (6), (3). A common design objective is the discharge of not more than 0.30 pounds of solids per 1,000 pounds of gas adjusted to 12% CO_2 (25). Harmful gasses are largely removed by water scrubbers (3), (20), (25), but are unaffected by centrifugal collectors, electrostatic precipitators and filter bags. Odours resulting from sludge combustion are only removed by subjecting the exhaust gasses to high temperatures in the range of 1200 to 1500°F, depending on the sludge characteristics(20).

A secondary problem created by the use of water scrubbers for the control of air pollution is that of the disposal of the scrubber water containing solids and dissolved gases removed from the incinerator exhaust. The scrubber water is usually directed to a settling basin where most of the ash settles out (20) and the supernatant is returned to the sewage treatment process. The supernatant will contain some fines and dissolved gasses, which for the most part will end up in the plant effluent. The settled ash adds to that remaining from the sludge combustion in the incinerator. Also the volume of water that is involved in a scrubber operation necessitates a considerable capital and operating cost for settling basins, pumps, etc. Dalton et/al, (3) state that the scrubbers used in Chicago require three gallons of water for every gallon of sludge processed by heat drying.

A fourth problem with incineration is the relative complexity of the process which requires a high degree of technical competence on the part of the maintenance personnel for electrical and mechanical repairs (23). This in turn increases operating costs.

A fifth problem that can be created by employing incineration occurs at existing sewage treatment plants which already include sludge digestion facilities. Sludge digestion prior to incineration would serve no useful purpose but rather it would increase the auxiliary fuel requirements of the incinerator. Hence the digestion facilities are rendered obsolete and the operating agency is faced with the redundancy of a large capital expenditure.

The sixth problem is that as in the case of sludge disposal by dumping, disposal by incineration does not conserve the valuable properties of the sludge itself. This important factor will be discussed at greater length in section 2.4.3 of this report.

2.4.1.2 Disposal Site Feature and Management Procedures

The following are suggested optimum characteristics and management procedures for land to be used for land disposal. The characteristics are intended for land which is to receive a "heavy" sludge application under Ontario climatic conditions. Heavy application may be defined as one which approaches the limitations of the vegetation on the land to consume the nutrients in the sludge during the growing season. This limitation will depend on the type of vegetation, whether or not it is cropped and how often it is cropped.

The land should be as flat as possible to minimize surface water runoff. It is suggested that the maximum sustained slop should be 5%. Where runoff cannot be prevented (by measures to be discussed subsequently), it should be contained within the disposal site. This could be accomplished by construction of peripheral earthen dykes in low areas and/or one or more internal dyke. Contour furrows could be ploughed into the land whether it is cultivated or not, to promote the retention of surface water.

If the slope of the land is significant (greater than say 3%) then the soil should be a reasonably permeable one to promote absorption of surface water thereby inhibiting runoff. It is suggested that the soil have a permeability coefficient of at least 10^{-5} cm/sec. Teng (33) describes soils with coefficients of at least 10^{-4} as having good drainage quality. Also a permeable soil would tend to provide a more stable road base for cases where sludge is applied by vehicles.

In cases where soil permeability is not a prerequisite, a soil with a high clay content may be preferable as the amount of sludge that can be tolerated by such a soil is greater due to its superior buffering capacity (65). Also leachate retention (and hence stabilization) in an impermeable soil such as a one with a high clay content, would be increased.

The land should be used to produce a crop regularly. Besides putting the valuable properties of sludge to use, this would increase the soil's capacity to assimilate more sludge by removing nutrients and preventing accumulation to the extent that surface and ground water contamination and soil toxicity occurs. When choosing crops, their "soil cover" characteristics should be weighed against their nutrient uptake capacity and amenability to fertilization with digested sludge. Most grasses, for instance, would be superior to corn or soybeans from the standpoint of controlling surface water runoff (27) but the latter would likely consume more nutrients per acre planted.

When the land is being cultivated, and if the slope of the land is significant (greater than 3.% say), the practises of contour strip cropping and crop rotation should be employed as these are recognized erosion control measures (32), (27), and as such will control runoff. Also the practise of "zero tillage" could be considered. Vehicles used for spreading sludge on cultivated land should travel parallel to land contours to avoid causing oblique ruts. Another runoff control measure that might be employed would be the establishment of permanent uncultivated contour strips say 10 feet wide, 200 feet apart, planted with a good cover crop.

The ground water table should be low, in order to provide retention time for biological treatment of the percolating surface water before reaching the ground water table. Also a high water table will inhibit the reaeration of the biologically active zone in the soil. Schwartz and Bendixen (17) recommend a depth of not less than 5 feet for soil used to assimilate waste water.

It would be preferable if the land were not drained by field tile. This provides retention time for biological treatment of the percolating surface water before reaching a surface water course. Also if sludge is being spread by vehicles, there is the possibility of damage to the tile system if the vehicle is large and the tile system is shallow.

The land should be remote from surface water courses to lessen the possibility of contamination of same with surface water runoff or with percolating ground water. It is difficult to recommend a minimum distance for all sites as the necessary distance will depend on all the other land features as well as the nature of the surface water course. However, it is suggested that a minimum distance of 200 feet would suffice if the land was essentially flat. If the land sloped at 5% towards the water course, a minimum distance from the water course of 500 feet should be considered even with the good site management practises mentioned earlier.

Remoteness from human habitation is a desirable feature for land used for disposal of digested sludge. Even though good application practises should preclude odour problems or drinking water contamination, a minimum distance of 300 feet between habitations and disposal site would be an adviseable precaution. A separation of 2000 feet should be maintained from any area of residential development.

The disposal site may require provision for temporary storage of sludge in the form of an earthen lagoon, during times of wet field conditions. Also if sludge is to be applied to land during crop cultivation (e.g., by spray or ridge and furrow irrigation) then sludge storage may be required during certain periods of growth or harvesting. If the sewage treatment plant does not have adequate storage (e.g., in digesters, lagoons or drying beds) then the remaining storage requirement should be met by the facilities at the disposal site.

From the standpoint of restriction on mobility of spreading equipment, it is suggested that storage for one month should be available for plants in Southern Ontario and two months in Northern Ontario. The storage required to facilitate cultivation will have to be assessed individually but it need not be considered additive to that for wet weather if provision is made to withdraw the sludge from the lagoon as soon as field conditions permit. It is suggested that even if full storage is available at the plant, a small storage lagoon might be desirable at the disposal site for emergency use. The design of any sludge storage lagoon at a disposal site should be in accordance with accepted criteria for sludge storage lagoons (63).

2.4.1.3 Rate of Application

Table I lists sludge application rates which have been discussed in the literature. Part (a) of the table lists rate intended for application of sludge on a repetitive annual basis while part (b) pertains to rates intended for single or infrequent application. There are considerable differences among these values indicating the use of different criteria for determining allowable rates.

The desirable rate of applying sludge to land (i.e., the tons of solids per acre per year) will depend on several factors. Good compliance with the optimum disposal site features and management procedures discussed earlier will favour higher application rates. A warm dry climate and a well digested sludge with low moisture content, would also favour higher rates. However, the most rational way to estimate the allowable application rate would appear to be from estimates of the nutrient uptake of the particular crop being cultivated. This would be particularly true if it is intended to apply the sludge on a repetitive annual basis as opposed to single or infrequent applications.

In considering nutrient uptake by crops, nitrogen, phosphorus and potassium are of particular importance as they are required by plants in relatively large amounts and one or more is usually deficient in Ontario soils (32). A brief discussion of these three elements would be beneficial at this stage.

Nitrogen is available to plants primarily in the nitrate form hence the rate of conversion of the total nitrogen in sludge to nitrate nitrogen (nitrification rate) is important. Burd (6) states that studies by the U.S. Department of Agriculture determined that the rate of nitrification for sludge was about 20 to 25% complete after sixteen weeks under optimum nitrification conditions. Hinsly and Sosewitz (2) and Jones (26) state that digested sludge application rates which supply nitrogen in amounts of greater than those need for crop production will increase nitrogen in drainage water. Water supplies containing more than 45. mg/l as nitrate nitrogen are a hazard to the health of animals and humans. Another reason for not over-fertilizing with any form of nitrogen is that certain crops will yield a high nitrate fodder which can cause nitrate poisoning in livestock. The Department of Agriculture (45) state that nitrate poisoning of livestock will occur from consuming silage or green forage containing in excess of .3% nitrate on a dry weight basis.

In contrast with nitrogen, phosphorus is a relatively immobile nutrient and once in contact with soil, it becomes quite strongly bound and is not lost by leaching (64), (32), (26). Phosphorus in fresh organic matter is moderately available to crops (26). Soil pH is an important factor influencing the availability of phosphorus. A certain build-up of phosphorus in the soil (beyond the crop's needs) does not interfere with crop production (45).

Potassium may be lost from soils by leaching. It is readily available to plants when in the form of fresh organic matter (32). Like phosphorus a certain accumulation of potassium in the soil (beyond the crop's needs) does not interfere with crop production (45).

TABLE I

SLUDGE APPLICATION RATES FOR ANAEROBICALLY DIGESTED SLUDGE

A. FOR REPETITIVE ANNUAL SLUDGE APPLICATION

Plant	Sludge T.S. (%)	Application Rate (tons of solids/ acre/year)	Reference	Remarks
-	3.44	25.	6 (p. 25)	Achieves crop growth rate equal to that of commercial fertilizers applied at conventional rates.
Chicago Ill.	3.3	7.46	3 (p. 798)	Satisfies nutrient requirements of corn (estimate only).
-	-	100.	12	Can be applied to sandy soils for extending periods without resulting in a detrimental accumulation of organic residues in the soil.
Chicago Ill.	2.8	7.7 to 29.4	2 (p. 827)	Various rates used on corn and soybeans crop land for one season with all crops responding favourably.
-	3.44	100.	6	Can be applied at this rate without impairing the growth of crops.
Canton Ohio	-	74.	3 (p. 803)	Average rate applied over a period of 40 years to 600 acres of municipality owned land, partially cultivated.
Chicago Ill.	7 10.0	25.	58 (p. 24)	Applied to alfalfa, soybeans and corn.
Springfield Ill.	6.0	61.	64 (p. 396)	-
San Diego Cal.	6.5	10. to 100.	64 (p. 396)	-

B. FOR INFREQUENT SLUDGE APPLICATION

Chicago Ill.	3.0	100	2 (p. 830)	Sludge used to enrich poor quality soil and develop lush grass cover suitable for recreation.
-	-	5	24 (p. 35)	Sludge used to stabilize piles of tailings from copper mine and resulted in improved germination and growth of vegetation.
Maple Lodge Work, Eng.	4.0	2.5	50	Sludge used on agricultural land.
St. Marys, Penn.	4.1	3.0	50	Sludge used on agricultural land.
Penn. Communities	-	2.0	50	- As above -

By way of illustration of the important effects agricultural fertilizers have on surface waters the following is a summary of work done by Terry & Salback (56). Tests were made on the Catfish Creek and the Duffin's Creek watersheds, two predominately rural watersheds of similar size located in Ontario. Three times as much nitrogen and phosphorus is applied per acre to the Catfish Creek basin as is applied to the Duffin's Creek basin. A comparison between the contributions of nutrients from municipal - industrial sources and rural land drainage revealed that 95% of the total N load and over 75% of the total P load in the Catfish Creek watershed appeared to have rural origin. By comparison in the Duffin's Creek basin about 89% of the N and 50% of the P load was contained in the rural land drainage.

In consideration of the foregoing discussion of the interrelationships between nitrogen, phosphorus and potassium and soils, it would appear that a major factor in selecting a sludge application rate, would be to supply as much of the crops requirements for P and K as possible, without greatly exceeding its requirements for N. If excess N is a problem at a particular sludge application rate, then it may be possible to deplete the soil of excess N by the use of soil and water management practises which encourage denitrification (2), (64).

The following table indicates the sludge application rates required to replace the annual uptake of N, P and K by 3 common Ontario crops. The table is based on an assumed sludge content of 4.%N, 2.%P, and .5%K, (as a % of the total solids).

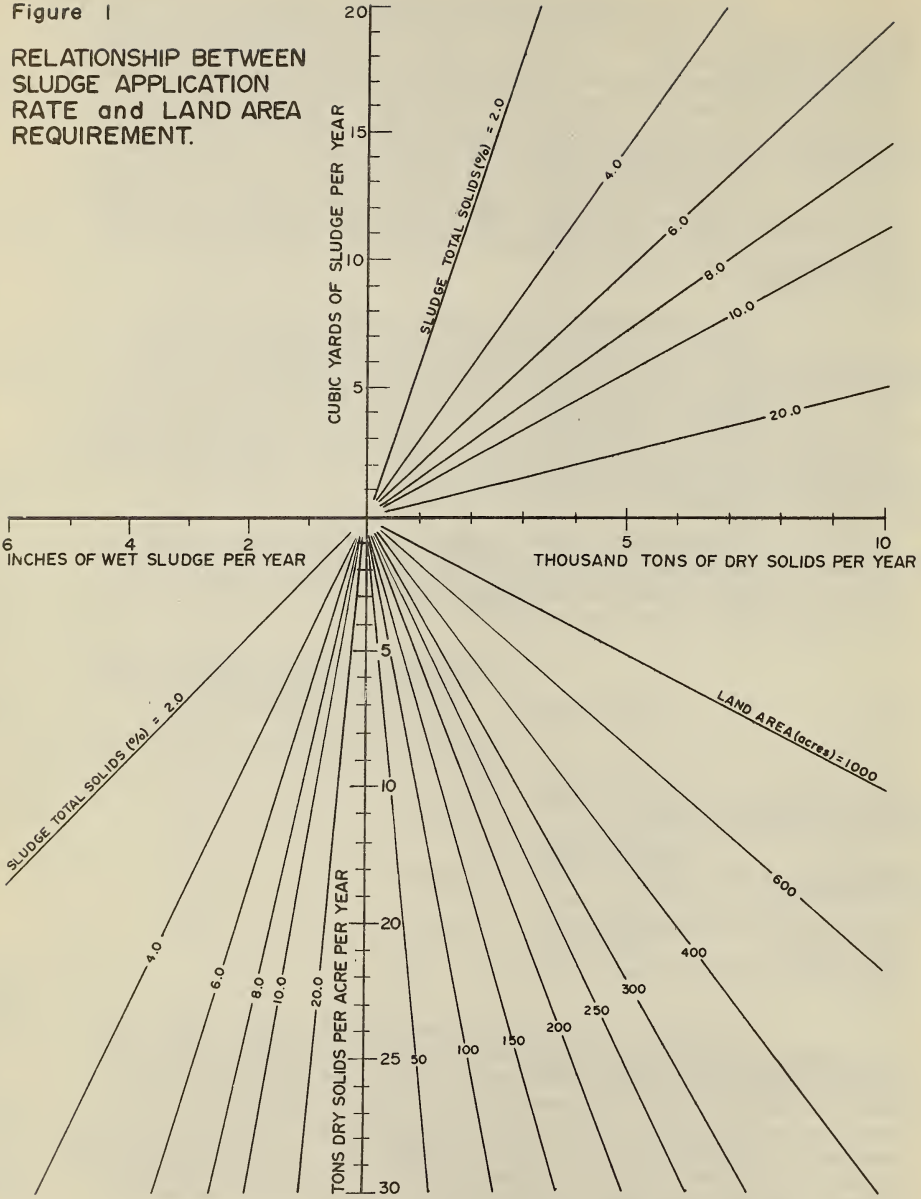
Crop	Assumed Yield	Sludge Application Rate Required to Satisfy Nutrient Requirements (in tons dry sludge/acre/year) N	P	K
Corn (grain stover & cobs)	75. bu. grain/ acre	1.52	.24	3.77
Soybeans (grain only)	25. bu. grain/ acre	1.37	.19	1.66
Sweet Clover Hay (whole plant)	5. tons/acre	2.31	.25	6.85

The above table assumes that all of the sludge's N, P and K is readily available to the crop during the growing season. This condition is unlikely particularly with respect to N. This fact would tend to make the figures in the table conservative. Some of the plant's nutrients may be generated from within the soil itself (e.g., by the fixation of atmospheric nitrogen by micro-organising in the soil). Some may be brought to the soil in rainwater (e.g., compounds of N + O created by lightning). Hence, it may be seen that nutrient uptake by crops can only be used as a guide in determining sludge application rates.

It would appear that the best means of determining the allowable sludge application rates would be by field or lab tests with the particular sludge and crop in question. This is due to the rather wide

Figure 1

RELATIONSHIP BETWEEN SLUDGE APPLICATION RATE and LAND AREA REQUIREMENT.



variations to be expected in the N, P and K concentrations in different sludges and to the variations in the degree to which these nutrients are available to crops. Also there may be harmful concentrations of other elements (such as heavy metals) in the sludge which may limit application rates. These will be discussed in sections 2.4.2 and 4.2.3 of this report.

Figure 1 of this report illustrates the relationships between sludge application rates and land area requirements. For example if a plant produced 40,000 yd^3/year of wet sludge at 4% T.S., 200 acres of land would enable an application rate of 6.5 tons of dry sludge solids per acre per year or 1.5 in. of wet sludge per year.

2.4.1.4 Frequency of Application

This section concerns the frequency of application of sludge during any given year. Frequent sludge application during a particular year would be desirable in that it would enhance sludge digestion by allowing a nearly continuous digestion process, reduce the storage space required for the sludge at the treatment plant and promote assimilation of the sludge at the disposal site by applying the total amount gradually. However, there are several factors which may limit the frequency of application.

Firstly, if sludge is being disposed of on agricultural land used for crop production then it will not likely be possible to continue disposal during the growing season. However if the sludge were applied by spray irrigation, ridge and furrow irrigation or spray pumping from a tank truck, disposal during part of the growing season may be possible. The method of application during the growing season must not physically damage the plants (e.g., by the forcefull ejection of the sludge against the plant, or by the passage of the spreading vehicle over the plant). Application to pasture land used for ruminants (e.g., cattle, sheep) could continue year round as no adverse effects to these animals are likely (64), (16).

If sludge is to be applied to crop land, application may have to be interrupted during seed germination. Hinesly and Sosewitz (2) found that sludge inhibited corn and soybean seed germination, due partly to its ammonium or ammonia content. They state that the seed should not be sown sooner than one week after sludge application, but do not state at what stage in seedling development that sludge application may be resumed. The authors state that there was no burning observed when sludge was applied through sprinkler systems on maturing plants. Hence it would appear that for corn and soybeans at least sludge spreading need not be interrupted during plant maturation.

Frequency of sludge application will also be affected by wet weather. Fall and spring precipitation may create surface water runoff problems. However if the land used for disposal is well chosen and properly managed (see section 2.4.1.2) then runoff considerations should not be crucial. Wet field conditions associated with fall and spring may hinder the mobility of certain types of vehicles used for spreading the sludge. It would be prudent to allow for one month interruption in Southern Ontario and two months interruption in Northern Ontario unless specially equipped vehicles are used.

2.4.2 Disadvantages

There are three main disadvantages of sludge disposal by land application compared with the other two methods. Firstly, sludge disposal by land application is subject to the local climatic conditions. In Ontario the low temperatures associated with winter would hamper or prohibit application by ridge and furrow or spray irrigation due to freezing of the sludge. However spreading from tank truck or manure spreader would still be quite feasible. The wet weather associated with spring and fall will interfere with the mobility of vehicles on land. Another important aspect of climatic influence on sludge disposal on land is the potential for contamination of surface water courses by runoff from the disposal site. This is particularly significant during spring thaws when the ground is still frozen. It is suggested that if the site is well chosen and managed and the proper rates and frequency of disposal are used (as discussed earlier) then the runoff problem will be minimal. However as climate will likely cause some interruption of disposal by land application, sludge storage facilities will have to be provided at the plant or in the field.

A second problem with land application is the need to regulate the quality of the sludge produced to ensure a beneficial product in cases where the soil fertilizing and conditioning properties of the sludge are to be utilized, or in other cases, to ensure a harmless product.

Thorough sludge digestion (anaerobic or aerobic) is a prerequisite for trouble free land application. Hinesly and Sosewitz (2) recommend that the volatile solids be no greater than 45% and that the pH be greater than 6.7. In addition to the public health problems involving pathogenic organisms, untreated raw primary sludge is not recommended for agricultural use because its physical structure and high grease content have a detrimental effect on the soil structure and the growing plants (10). Anaerobic digestion reduces the nitrogen content of sludge by 40. to 50.% (55). This is beneficial in that it allows a greater sludge application rate in cases where accumulation of excessive nitrogen in the soil is a problem.

The concentration of industrial wastes in the sludge must be kept within tolerable limits. Heavy metals (such as Cr, Zn, Pb, Mn and Ni), soluble salts, iron compounds and synthetic compounds may be beneficial for crop nutrition in certain concentrations but there are limitations

to the concentrations that can be tolerated particularly in connection with agricultural land.

Commonly, heavy metals in digested sludges are precipitated as sulphides and are associated with the solid phase. The concentration of metals in sludge may not be as potent as standard laboratory analyses would indicate. The organic material in sludge has the ability to form relatively insoluble compounds with the various metals in the sludge. This metal buffering action serves to isolate certain excessive amounts of metals and thereby serves as a means of detoxification (60).

Although there is information on the optimum and minimum concentrations of certain elements required for the growth of various plants (see section 2.4.3), there is somewhat of a scarcity of information regarding the maximum tolerable concentrations for various plants and the animals and humans that consume these crops. However Le Riche (13) states that foreign metals can evidently be retained in soil for several years at least, which emphasizes the danger of their accumulating when wastes containing metal-contaminated organic material are applied repeatedly. Although this experiment produced no evidence that crop yields were affected, abnormally large quantities of these metals were taken up by the plants, (carrots, potatoes, beets, leeks).

In studying the effects of heavy metal salts in mining tailings on tomato seed germination, Dean, et/al (24) report that 1,000 mg/l copper in the tailings had little effect, nickel concentrations above 100. mg/l were toxic and zinc concentrations above 10. mg/l were toxic. When using a composite of these elements, toxic effects become evident at 10. mg/l and became pronounced at about 100 mg/l. They state that the effect achieved at the low concentrations tested, indicates toxicity to be independent of osmotic pressure. Conn (61) stated that concentrations over 100. mg/l copper and 300. mg/l zinc in soil, are toxic to plant growth.

With regard to pollution of ground and surface waters by the leaching of heavy metals from the soil, Bucksteeg (47) thought that this would not be the principal problem created by application of waste water sludges to land. He noted that the solubility of metal hydroxides was low and was decreased by mixing with organic materials.

The control of adverse industrial wastes should be effected at the sources (i.e., at the industrial plant) where their concentration is greatest. Treatment and often recovery for re-use is generally most practical at this point. However toxicity due to excessive copper, boron and zinc can be counteracted by adding lime to the sludge to precipitate excessive amounts of these elements (39), (16).

A third problem with sludge disposal by land application is the surface water with pathogenic organisms. Ewing and Dick (64) state that available information tends to confirm that the hazard is not great (with digested sludge) and no incidence of disease is known to have been traced to sludge disposal operations. Although thorough digestion of sludge will destroy most pathogens, the danger of contamination still exists (55). Evans (16) states that the more common intestinal pathogenic organisms of a bacterial or viral nature may be expected to survive in soils under widely varying conditions from several hours to several months but rarely more than a year. E. coli, E. typhos and M. tuberculosis appear to be the most resistant. In a summary of literature pertaining to this subject Ewing and Dick (64) report that Salmonella typhosa populations are reduced by 85 percent with 6 days of digestion and by 92 percent in digestion with 20 days detention time. Endamoeba hystolytica were found to survive less than 12 days in digesters. Tubercle bacilli were reduced only one sixth after 35 days digestion. Some parasite ova and hookworms have also been found to survive usual digestion periods. E. coli are greatly reduced in numbers but not completely eliminated by digestion. Little data was available on the survival of viruses in digested sludge.

Ewing and Dick further state that tubercle bacilli and hookworms survive drying in sludge longer than typhoid organisms. Coliform organism die off has been shown to be over 99.9 percent in 80 days.

It has been reported that bacteria do not generally travel more than 100 feet through granular soils, that there is complete removal of E. coli in five meters of dune sand, and that viruses did not pass through a 2 foot bed of clean sand at moderate rates of application of liquid over a 7-month period (64). It is therefore expected that groundwater contamination with pathogens will not be a serious hazard but that concern for surface water pollution is justified.

The fact that some pathogens do survive digestion has led to the general recommendation that sludge not be applied to root crops or crops that are intended for human consumption in a raw form (63), (64). However there is a sufficient number of forage crops which can be grown in any given soil type so that there is no need for sludge application to soils used to produce other types.

Application of sludge to pasture land appears to present little problem from the standpoint of pathogenic organisms. Farm animals are reported to be strongly resistent to infection from eating raw sewage and sludge (16). Dalton, et/al (3) lists several cases of raw sewage and sludge application to pasture land with no ill effects to livestock. However dairy cattle might be an exception due to the possibility of udder infection.

2.4.3 Advantages

There are four main advantages to the method of land application for sludge disposal. First, and most important, this method conserves the soil fertilizing and conditioning properties of the sludge. This factor will be increasingly significant as intensive farming increases. Ecological and economic

TABLE II

CONTENT OF ANAEROBIC DIGESTED SLUDGES

	Units	Chicago Illinois (2)			Washington D.C. (6)	Jasper Ind. (6)	Richmond Ind. (6)	(6) Avg. Values		San Diego Cal. (6)	Chicago Ill. (3)	Avg. Values (6)
		July 1966	July 1966	June 1967				1951 to 1955	1931 to 1935			
Total Solids	%	2.75	2.93	3.43							3.44	3.3
pH		7.0	7.1	7.7								
Grease	%T.S.										11.15	
Ash	%T.S.				52.8	37.0	50.1					
Humus	%T.S.											
Alkal. ($CaCO_3$)	mg/l	2745	2750	2460								
C	%T.S.	52.0	54.9	48.1	28.6	23.0	26.4					
N - Total	%T.S.	5.50	4.95	5.15	2.06	5.89	2.24	2.4	2.2		2.73	5.0
- NH_3	%T.S.	1.92	2.06	2.30								
P - Total	%T.S.	2.47	2.52	2.16								3.0
- P_2O_5	%T.S.				1.44	3.49	4.34	2.7	2.1		4.78	
K	%T.S.	.415	.519								**.83	.5
Al	mg/l		227	636								
As	"		*									
B	"	.9	1.9	5.1						9		
Cd	"	1.9	1.0	3.4								
Ca	"	1180	1240									
Cl	"	490	490	170							7500	
Cr	"	46	49	26								
Co	"			*								
Cu	"	32	24	31						643		
Fe	"	1666	1598	1500								
Mg	"	332	291	446								
Mn	"	143	14							262		
Mo	"		.06	*						6		
Na	"	129	119								10700	
Ni	"	+	2	3								
Pb	"	90	90	6								
Si	"		9800	2773								
S	"	45	67	288								
Zn	"	92	91	90						2459		

* Below Detectable Limits + Trace ** As K_2O

considerations demand the recycling of "waste" material back to the land. The recycling of sludge cannot be considered a complete remedy to the problems of intensive farming, if for no other reason than the fact that there is an insufficient quantity to treat all agricultural land. However it could be of great assistance particularly around heavily urbanized areas. A somewhat lengthy discussion of the soil fertilizing, conditioning and irrigating properties of sludge is presented hereafter due to the importance of these properties.

Table II of this report lists concentrations of the various components in anaerobically digested sludges extracted from the literature. Burd (6) states that aerobic digestion of sludge retains even more of the sludge's basic fertilizer value than does anaerobic digestion. By way of comparison, standard commercial fertilizers generally contain N, P and K primarily. The value of a nutrient in any fertilizer is dependent on the total quantity present as well as the availability of it to growing plants. For example, nitrogen is available to plants primarily in the nitrate form, hence the rate of conversion of total nitrogen to nitrate nitrogen (nitrification rate) is important. Burd (6) reported studies by the U. S. Department of Agriculture which determined that the rate of nitrification for sludge was much less than that of ammonium sulphate (the prime nitrogen source in commercial fertilizers). Less than 20 to 25% of the sludge nitrogen was converted to the nitrate form in sixteen weeks under optimum conditions for nitrification. The conversion was 90% for ammonium sulphate. However it would appear that if sludge is applied on a repetitive basis, the rate of conversion of total nitrogen and other nutrients to the form available to plants becomes less significant because after an initial lag period the slow conversion of nutrients from any one sludge application would be compensated for somewhat by the continuing conversion from previous applications.

Evans (16) reports that nitrogen fixing bacteria may be present in sludge in large numbers. These micro-organisms are capable of transforming molecular nitrogen in the air to nitrogenous compounds which can be assimilated by plants. This may however be a disadvantage in cases where sludge application rates are limited by nitrogen content.

In addition to providing nitrogen, phosphorus and potassium, sludge provides many other substances for plant growth which are not contained in standard chemical fertilizers. Evans (16) reports that 20 or more elements are beneficial to plant growth and at least 16 are essential. All 16 essential elements and possibly other nutrients and growth stimulators, are found in digested sludge. The Ontario Department of Agriculture (32) list 16 essential plant nutrients and typical concentrations of these nutrients in plants, as follows.

ESSENTIAL NUTRIENTS	CONCENTRATION IN DRY WEIGHT OF PLANT
a) Macronutrients	
Carbon (C)	45%
Oxygen (O)	43%
Hydrogen (H)	6%
Nitrogen (N)	up to 3.0%
Phosphorus (P)	up to 1.0%
Potassium (K)	1.5 to 5.0%
Calcium (Ca)	up to 3.0%
Magnesium (Mg)	up to 1.0%
Sulphur (S)	up to 1.0%
b) Micronutrients	
Boron (B)	Less than 100 ppm
Copper (Cu)	Less than 100 ppm
Iron (Fe)	Up to 1500 ppm
Manganese (Mn)	Up to 1500 ppm
Molybdenum (Mo)	Less than 1.0 ppm
Zinc (Zn)	Less than 100 ppm

It is further stated that plants also contain sodium, iodine, chlorine, cobalt, silicon and aluminum but these elements have not been shown to be essential for growth nor has their function in plants been recognized.'

Carbon is supplied mainly from the carbon dioxide of the atmosphere and H and O, mainly in the form of water. N may be extracted from the atmosphere by certain nitrogen fixing plants. However, the remaining nutrients must all be obtained from the medium in which the plants are grown (soil). It is logical to assume that the continued depletion of these remaining nutrients by the current practises of intensive farming and limited refertilization (with N, P and K only) cannot continue indefinitely without detriment to future soil fertility. Hence, the nutrient content of digested sludge considerably enhances its agricultural value.

In addition to its soil fertilizing capacity sludge is a valuable soil conditioner by virtue of its considerable humus content. This factor would appear to be most advantageous in soils that were characterized by either a high clay content or a high sand content. Humus increases the water holding capacity of soil and hence will provide a controlled moisture supply to plants (3). Humus may make a soil more permeable and hence clay soils that drain poorly may be made more productive (32). Due to the increased permeability the soil may be made less susceptible to surface water erosion (27). Soil aeration would also be promoted. Humus contains polyphenolic compounds which solubilize rocks and minerals in soil, thereby making their components available to plants (59). Humus improves the

cation exchange capacity of soil (32). Humus added to a clay soil will reduce its tendency to swell and shrink with change in moisture content, which in turn reduces crack formation(32).

Another significant factor regarding the humus content of digested sludge is that the carbon to nitrogen ratio is well below the desirable maximum of 30:1 (32). An examination of the data in Table II reveals this fact. The C:N ratio is important because of the fact that heterotrophic soil bacteria require nitrogen as they decompose organic matter. If the organic matter is low in nitrogen as in staw (C:N = 80:1 for wheat straw) the bacteria use any soluble nitrogen which may be in the soil. A crop growing in the soil at this time may show signs of nitrogen deficiency (32).

In countries with an abundance of agricultural land, humus can be replenished by allowing fields to lie fallow for a year and then plowing in the cover crop. But as population increases, fallow land becomes more of a luxury and hence the recycling of humus-containing "wastes" such as sludge, becomes more of a necessity.

When sludge is applied in its undewatered state on a regular basis it will have a considerable irrigation value. This fact together with the improved moisture retention capabilities due to sludge solids will promote optimum plant growth conditions. Dalton et/al (3) state that two inches of water applied to a corn field when it is in tassle (a period of two or three weeks) results in an increased production of 36 bushels of corn per acre.

A second advantage of sludge disposal by land application is the freedom from the air pollution associated with disposal by incineration. This problem has been discussed under section 2.3.2 of this report. In view of the many other sources of air pollution inherent in today's urban communities, it is important that the method of disposal of the community's sludge not aggravate the situation.

A third advantage of land application is the fact that it is not necessary to dewater the sludge as is the case with most incineration methods, (see section 2.3.2). This eliminates the problems of recycling the nutrients and fines in the water extract back to the sewage treatment plant, as well as the associated high capital and operating costs.

Fourthly, land application can solve the complete sludge disposal problem into perpetuity. The problem of finding more and more disposal sites as in the case of sludge disposal by dumping and the problem of disposing of residual ash from incineration, are avoided.

2.5 Transportation of Sludge

Transportation of sludge is of considerable significance in sludge disposal by dumping and by land application. This is not the case with incineration as the incinerator is usually located on the sewage plant site and the volume of sludge remaining for disposal as residual ash is greatly reduced.

In the case of land application and dumping, the availability of disposal sites is usually directly proportional to the distance between site and plant and hence there will be an optimum transportation distance for lowest overall disposal cost for any one particular plant.

Any study of the economics of sludge transportation must be accompanied by a study of sludge dewatering and a short digression on this topic would be appropriate at this time. Modern high rate mixed digesters commonly produce sludge having 3. to 5.% total solids, (i.e., 97. to 95.% water) (64). Sludge dewatering may be desirable or necessary from the economic standpoint to reduce the volume of sludge to be handled. However it should be remembered that dewatering has certain disadvantages. Firstly, it may necessitate the recirculating of nutrient rich centrate, filtrate, etc., back to the sewage plant which could create significant problems (see section 2.3.2). Secondly dewatering may preclude sludge transportation by pumping, as pumping of sludge with a total solids content greater than 5.% may increase pumping costs prohibitively (7). Thirdly, dewatering is undesirable from the standpoint of conserving the nutrient value of the sludge. Dalton et/al (3) state that the liquid portion of the sludge contains only a small portion of the nitrogen and phosphorus but a large portion of the potassium. Other dissolved elements will be lost as well.

Transportation of sludge can be accomplished by truck, (tank or open box type) pipeline, or a combination of the two. Long distance transportation of sludge by pipeline is a relatively new concept and hence there is a scarcity of information on this topic. Rail transportation of sludge may be practical if the facilities are readily available and if the quantities of sludge are large. The City of Chicago recently let a contract for the disposal of approximately 20% of its sludge, which involves the transportation of the sludge about 160 miles by rail (59). A 36 car train leaves Chicago each day carrying about 1500. tons of sludge.

Factors affecting the choice between trucking and pumping of sludge to the disposal sites include: volume of sludge to be disposed of, distance (cross-country and by road) from sewage plant, solids concentration of the sludge, elevation difference between plant and disposal site, and characteristics of the sludge (e.g., grease content, temperature, solids settleability), presence of large solid (tramp) materials and possible scaling tendencies, (e.g., sludge with high lime content).

Small sludge volumes tend to favour trucking as the mode of transportation. Raynes (7) states that, "Cities with population greater than about 1.5 million produce relatively large quantities of sludge slurry daily and so the design of pipelines for economic continuously operated transport is reasonably conventional. Small cities generally produce so little slurry that economic design for transport in small pipes (perhaps under 4 in.) is more of a challenge." In the Bechtel Corp. study of regional waste management systems

(14) it was concluded that pipelines were the most economical form of transport to land disposal sites for regional systems involving more than five tons/day of digested sludge solids. Combined pumping and disposal of sludge from more than one sewage plant should be evaluated where possible.

Long distances between sewage plant and disposal site tend to favour pipelines although short distances would not rule out same. The Metropolitan Sanitary District of Greater Chicago is considering the pumping of all its sludge for a distance of about forty miles to marginal farmland. Riddel and Cormack (49) concluded that for digested sludge at 3.5% solids, trucks would provide the most economical means for sludge transportation for cities smaller than 10,000 people for distances less than 150 miles, when rail transport became competetive. For 25 mile hauls, pipelines were found economical for cities with populations larger than 60,000.

With regards to sludge solids concentration, Raynes (7) states that for solids concentrations above 5%, the friction head losses to be suffered in operating in the turbulent flow range, are such that despite the reduced volume of material to be transported, dilution to 5% provides economic advantages. Velocity magnitude associated with turbulent flow are desired to keep the settleable solids in suspension. For solids concentrations up to 25%, truck haulage in water-tight tank trucks is usually required (1).

Large differences in elevation between sewage plant and disposal site increase capital and operating costs for pipelines and trucking but pipeline costs would probably be influenced to a greater extent.

Sludge characteristics such as high grease content, low temperature, high specific gravity solids, presence of large solid (tramp) material and scaling tendency would adversely influence disposal by pipline more than by trucking.

Costs of pumping sludge have been estimated by Rayne (7) as a function of transport distance and population for a sludge with 5% T.S. concentration. Burd (6) estimates that an average cost for piping sludge for "moderate" distances would be $5/ton dry solids.

2.6 Sludge Disposal Costs

Table III of this report lists some capital and operating costs for sludge disposal, that have been extracted from the literature. In reviewing the costs, it should be appreciated that certain costs associated with a disposal method are intangible and hence are not included in the costs listed. Such intangibles include the costs of polluting air, water or soil and the ultimate cost of wasting the useable properties of sewage sludge.

The year in which the costs were published should be noted when comparisons are made. Also plants in warmer, drier climates would be expected to incur lesser costs for sludge disposal by land application than those in other climates.

In general, from the literature reviewed, it would appear that land application costs are somewhat less than incineration costs for large and small communities. Insufficient data was obtained for sludge disposal by dumping, to make a comparison.

3 SUMMARY OF SLUDGE DISPOSAL AT OWRC OPERATED PLANTS

3.1 Disposal Methods

Table IV and V found in Section 7 of this report, list OWRC operated plants which during 1970 disposed of sludge by dumping and by land application respectively. The following chart summarizes the disposal methods.

DISPOSAL METHOD	NO. OF PLANTS
Land application (exclusively)	27
Dumping (exclusively)	19
Incineration	0
Land application and dumping	10
No sludge disposal	3
	59

The plants which used both land application and dumping, used the latter method primarily as a temporary expedient during inclement weather. Also many of the 27 plants listed as using land application exclusively have temporary storage lagoons used during bad weather. This distinction here is that it is intended to withdraw the sludge from these lagoons and apply it to the land at some time in the future, whereas this is not the case at plants listed as using "dumping". Of the 10 plants using land application and dumping, seven are in the "South Peel" complex.

Also contained in Table IV and V are some characteristics of the disposal sites. With regard to ownership of the disposal sites, the following chart is a summary.

OWNERSHIP OF SITE (S)	NO. OF PLANTS	
	Disposal by Land Application	Disposal by Dumping
Private Individual (s)	27	13
Contractor	2	4
Municipality	1	12
OWRC	1	0
Private individual and contractor	4	0
Private individual and municipality	2	0
Total	37	29

3.2 Disposal Costs

3.2.1 Preamble

Table VI found in Section 7 of this report, lists all the OWRC operated sewage treatment plants in operation during 1967, 1968 and 1969 and gives the available data on sludge quantities, types, disposal methods and disposal costs for these years.

The disposal costs given include only the cost of transporting the sludge from the treatment plant to the disposal site and the cost of actual disposal. The costs of digestion and dewatering of the sludge prior to disposal are not included. At most of the plants the work is performed by private individuals or firms through the letting of a contract, or simply on a per truckload basis. Section 7 of this report contains a typical sludge hauling contract for OWRC operated plants. At a few plants the task is perfomed by plant staff or local municipal works departments and hence there may be no available costs for sludge disposal at these plants (e.g., Port Dover, Trenton). Unless otherwise noted, the sludge disposal costs given are for disposal by private concerns.

In some plants the cost of ultimate sludge disposal is greatly reduced or non-existent due to the fact that the sludge is still being deposited in sludge drying lagoons whose volumetric capacity has not yet been exceeded. The Kitchener and Nepean Township plants are examples.

In the case where payment for disposal is made to private concerns, the costs will indirectly include capital costs (such as for trucks or land) as well as operating costs. However, in other cases, the costs given should be considered as operating costs only.

The total cost for any one year has been derived from the product of the cubic yards of sludge produced each month times the disposal cost per cubic yard in effect for the greater part of that month. Conversion of cost per cubic yard of sludge to cost per ton of dry solids has been calculated using the average total solids concentration in the sludge for the year as obtained from periodic grab samples of the sludge. In calculating cost per ton of dry solids, sludge specific gravity was assumed to vary with total solids concentration and values used were derived from studies by Chow (8).

3.2.2 Cost Analysis

Table VII of this report, summarizes the available sludge disposal costs for all OWRC operated plants during 1967, 1968 and 1969. The data used were taken from Table VI. For a number of plants the data regarding sludge volumes disposed of and costs of disposal were partly or wholly unavailable and hence the figures given are not entirely representative.

When listing sludge volumes disposed of all types of sludge (e.g., raw raw dewatered, digested, digested dewatered) have been included. The total operating costs for the plants in any one year is estimated to be within $\pm$ 5% for the actual cost for the calendar year due to possible carryover of billings from one year to the next.

Reviewing total volume of sludge disposed of in 1967, 1968 and 1969, relative to the number of plants in operation, the considerable increase from 1967 to 1968 appears to be followed by a levelling off in 1969. This trend is partly accounted for by the small volume of sludge produced or recorded by the 7 new plants in 1969. Also a large volume of sludge from the Kitchener plant (approximately 45,000 $yard^3$) was not included because ultimate disposal has been postponed. It is of interest to note that of the recorded 489,178 cubic yards of sludge disposed of in 1969, approximately 23% emanated from the Lakeview plant in South Peel.

The total cost of sludge disposal in 1967, 1968 and 1969 exhibits a similar trend to that for total sludge volumes disposed of. The reasons for this are believed to be similar to those listed for sludge volumes Of the $466,945 cost incurred in 1969, approximately 30% is associated with the Lakeview Plant.

TABLE VII

SUMMARY OF SLUDGE DISPOSAL COSTS
FOR OWRC OPERATED PLANTS

	1967	1968	1969
No. of plants in operation	50	52	59
Total volume of sludge disposed of (in cubic yards)	329, 123 (1)	433, 254 (2)	489, 178 (3)
Total cost of sludge disposal	$287, 413 (4)	$413, 817 (5)	$466, 945 (6)
Average cost of sludge disposal (per cubic yard)	$0.872	$0.955	$0.955
Total operating cost for plants	$2, 582, 493	$2, 972, 666	$3, 359, 295
Sludge disposal costs as a percentage of total operating costs	11.1%	13.9%	13.9%

NOTES:

1. Volumes exclude part of the sludge from Galt and Lakeview and all the sludge from Parry Sound, Coniston, Kingston Township, Markham, Nepean Township, Simcoe, Waterdown, Paris, Elora, Westminster Township and Frankford.

2. Volumes exclude part of the sludge from Chatham, Markham and Kitchener and all the sludge from Kingston Township, Nepean Township, Simcoe, Paris, Westminster Township and Frankford.

3. Volumes exclude part of the sludge from Chatham and Kitchener, and all the sludge from Nepean Township, Simcoe, Elora, Paris, Westminster Township, Frankford and five South Peel plants.

4. Costs exclude part of sludge disposal at Galt, Brampton/Chinguacousy, Lakeview and Streetsville and all the sludge disposal from Parry Sound, Port Dover, Trenton, Coniston, Kingston Township, Markham, Nepean Township, Simcoe, Waterdown, Elora, Paris, Westminster Township and Frankford.

5. Costs exclude part of sludge disposal at Chatham, Brampton/Chinguacousy, Lakeview and Streetsville and all the sludge disposal at Port Dover, Trenton, Coniston, Nepean Township, Simcoe, Paris, Westminster Township, Elora and Frankford.

6. Costs exclude part of the sludge disposal at Chatham, Kitchener, Markahm and Port Colborne and all sludge disposal at Port Dover, Trenton, Coniston, Nepean Township, Simcoe, Elora, Moosonee, Westminster Township, Frankford and five South Peel plants.

3.3 General Problems Encountered

3.3.1 Local Municipal By-Laws

Several OWRC operated sewage plants have experienced difficulties with sludge disposal due to prohibitive or overly restrictive municipal by-laws. The problem frequently occurs in cases where sludge from one municipality (e.g., city, town or village) is to be disposed of in an adjacent municipality (e.g., township). The latter municipality is likely to disapprove of this import of sludge within its boundaries especially if the quantities of sludge are large. However, the problem has also occurred in the case where sludge from a municipality is to be disposed of within a part of that municipality.

Section 379, (1), 112, of the Municipal Act grants local municipal councils the power to pass by-laws "for prohibiting within the municipality of any defined area or areas thereof for dumping or disposing of garbage, refuse or domestic or industrial waste of any kind." This section further states that the council may itself define industrial or domestic waste. Section 242, (2) of the same Act states that "a by-law passed by a council in the exercise of any of the powers conferred by and in accordance with this Act, and in good faith, shall not be open to question, or be quashed, set aside or declared invalid, either wholly or partly, on account of the unreasonableness or supposed unreasonableness of its provision or any of them."

This concentration of power in the hands of a municipal council has the potential for preventing or interfering with a method of sludge disposal which may be economically and ecologically beneficial for the municipality in question and neighbouring municipalities. The power of municipal councils are tempered in some cases by the over-riding powers of the Ontario Municipal Board (see section 3.3.2.4 of this report). when it is called upon to act in its capacity as arbitrator in disputes involving a municipality. Nevertheless, the municipality retains much control over sludge disposal within its boundaries because of the reluctance on the part of the OWRC to initiate OMB arbitration in disputes between itself and municipalities. This is due to the time and effort required to complete arbitration proceedings and to the ill-feeling that the proceedings and the settlements may create with municipalities.

The unfortunate attitude of some municipal councils towards sludge disposal, contradicts the symbiotic relationship which must exist between neighbouring rural and urban communities. The urban community serves the rural one by providing a market for its agricultural, sylvan, and mineral products, by providing a source of essential services and manufactured goods, and often by providing a direct source of employment. Hence

it is reasonable to expect that the rural community should reciprocate by assisting in the disposal of the waste that it helped to generate, regardless of the location of municipal boundaries. Where sludge is disposed of by proper land application, the rural community stands to gain from its considerable agricultural value.

The problem of prohibitive or overly restrictive by-laws regarding sludge disposal may be the result of "petty politics" or self-interest but the basic reason is generally the fact that many municipal councillors, particularly in the smaller communities, do not have access to the necessary technical information to enable them to make a sound long-term decision in this regard. Another factor that has come to light only recently is the encouragement given to municipalities by the Department of Energy and Resources Management, to pass restrictive or prohibitive by-laws for the disposal of all wastes including sewage sludge.

Assuming that the Department of Energy and Resources Management is to have jurisdiction over sludge disposal (see section 3.3.2 of this report), it will be necessary to negotiate with the Department to resolve the problems that it is creating for the operation of sewage treatment plants by the OWRC. This matter will be discussed further in section 3.3.2 of this report. In addition, it is suggested that the OWRC undertake a public relations effort, to expound the necessity of sludge disposal, the innocuous nature of digested sewage sludge, and in the case of the land application method, to expound the benefits which acrue. This effort should be directed towards municipal officials and the agricultural community primarily. Concurrent with thispublic relations effort, there should be increased supervision on the part of the OWRC and the other regulator bodies involved, over the disposal of sludge to ensure its successful implementation.

The problem of restrictive or prohibitive municipal by-laws is one which has the potential of disrupting the proper disposal of sludge at almost every Ontario sewage treatment plant. It is thus imperative that the OWRC take steps to alleviate this unfortunate situation as soon as possible.

3.3.2 Jurisdictional Conflicts Between Provincial Bodies

3.3.2.1 Background

The focusing of attention on ultimate sludge disposal is a farily recent occurrence in Ontario. As a result there is a general lack of definitive policy on the part of the various provincial bodies. However, the rapid growth of urban areas in the Province and the consequent reduction in availability of disposal sites has necessitated more attention to the problem.

Among the provincial bodies actively involved in sewage sludge disposal are the OWRC (through its Divisions of Sanitary Engineering and Plant Operations), the Department of Energy and Resources Management Branch) and the Department of Municipal Affairs (through its Community Planning Branch and the Ontario Municipal Board). In addition, there are several other Provincial and Federal bodies which have become involved to a limited degree or which have the potential to do so.

Section 16 (c) of the OWRC Act gives the OWRC the power to construct, acquire, provide, operate and maintain works and to receive, treat and dispose of sewage delivered by municipalities and persons. Sludge is an integral part of sewage being merely a portion of the solids matter in the sewage, and of the dissolved matter which has been converted to solids form through biological or chemical action. It cannot be thought of as a separate type of waste divorced from sewage. Hence, one would assume that the OWRC would have complete jurisdiction over ultimate sludge disposal. However, this is not the case and the multiplicity of existing jurisdictions has given rise to a situation characterized by duplication, contradiction and general "red tape".

Perhaps the main reason for the existing situation is the failure of the OWRC and its predecessor, the Department of Health, to insist that the method of ultimate sludge disposal be incorporated into the design of sewage treatment works. Thus far it has been omitted and left to the operating agency. In the past, the OWRC's Division of Plant Operations and many individual municipalities have found that the most efficient means of effecting sludge disposal, was generally to let a contract to a private individual or firm. In the case of OWRC operated plants and others, the terms of this contract transfers ownership of the sludge to the contractor and essentially confers the burden of proper disposal on him.

In many cases, the contractors have not had the technical knowledge or desire to ensure proper disposal. Hence, intervention of other Provincial bodies has been invited. Other factors tending to cause this intervention are the general decline in availability of sludge disposal sites, and the increased public awareness and concern over environmental pollution in general.

Another situation tending to complicate the matter of jurisdiction over sludge disposal, is the rumoured movement underway to amalgamate the regulatory functions of the Department of Energy and Resources Management and the OWRC.

To illustrate the present jurisdictional problems regarding sewage sludge disposal, the various government bodies involved will be discussed hereafter, together with the legislation from which these bodies derive their powers.

3.3.2.2 Ontario Water Resources Commission

The OWRC derives its powers primarily from the OWRC Act. In addition to Section 16 (c) of the Act mentioned earlier, there are several other sections which pertain directly or indirectly to sewage sludge disposal. Section 3 (4) of the Act states that approval must be obtained from the OWRC for sewage works for the distribution of sewage on the surface of the ground for the purpose of disposing of the sewage. Since sludge is an integral part of sewage, it would appear that the responsibility for disposal of sludge by land application and certain types of dumping, is hereby vested in the OWRC.

Section 27 (1) states that the OWRC may levy a fine for disposing of any material of any kind in any place that may impair the quality of the water of any well, lake, river, pond, spring stream, reservoir, or other water or watercourse. Section 26 (1) charges the OWRC with the responsibility for supervision of all surface and ground waters in Ontario. Since a vital aspect of sludge disposal by land application and by dumping is the prevention of contamination of surface and ground waters, these two sections of the OWRC Act further reinforce the jurisdiction of the OWRC over sludge disposal.

Apart from these legal considerations, the OWRC is the most logical body to have jurisdiction over sludge disposal. The OWRC has uncontested control over all the treatment facilities for sewage per. se. This control may be direct (e.g. through the operating directives of the Division of Plant Operations or the design review of the Division of Sanitary Engineering) or indirect (e.g. through the enforcing of plant effluent standards by the Division of Sanitary Engineering and the Division of Industrial Wastes).

It is these facilities which determine the characteristics of the sludge generated (such as the solids content, state of putrescence, pathogen content, etc.) as well as the total amount and rate of generation of the sludge. Hence it is reasonable to assume that the OWRC would be best able to control the disposal of the sludge.

3.3.2.3 Department of Energy and Resources Management

A recent publication of the Waste Management Branch of the Department of Energy & Resources Management (9) states that "the Waste Management Branch is the arm of the Ontario Government established to co-ordinate public and private problems of waste disposal within the duties and responsibilities set forth in the Waste Management Act and Regulation and to serve as the clearing house on such problems where other Government Departments and agencies are concerned." The publication further states that sewage residue from sewage works subject to the provision of the OWRC Act is within the sphere of concern of the Waste Managemrnt Branch. In Section 1 (11) of the "Regulations Made Under the Waste Management Act 1970" it is stated that hauled liquid industrial waste includes sewage residue from sewage works that are subject to the provisions of the OWRC Act. In Section 2 (5) of the Regulation, hauled liquid industrial waste is included in the list of designated wastes.

In contrast to the above, Section 2 of the Waste Management Act states that the act does not apply to "any sewage or other works to which the Ontario Water Resources Commission Act or the regulations thereunder apply." Nevertheless the Department of Energy & Resources is vigorously proceeding to include sludge disposal within its jurisdiction. This has been done by issuing directives to sludge haulage contractors and by encouraging municipalities to pass by-laws which embody the regulations of the Waste Management Act and which include sewage sludge in the definition of waste.

In cases where sludge is disposed of by dumping at sanitary landfill sites or open dumps which are used for disposal of other wastes as well well, it is probable that the Waste Management Act and the regulations made under the Waste Management Act would apply to these disposal sites. Standards for establishing, altering, enlarging, extending, operating and maintaining such sites would be enforced by the Department of Energy & Resources Management's Waste Management Branch.

Should sludge disposal by incineration be adopted at OWRC owned plants, approval for this method would probably come under the jurisdiction of the Department of Energy & Resources Management and the Department of Health. A minor technicality in the wording of the Waste Management Act would appear to prevent this at this time. Section 1 (j) of the Act defines "owner" as a person or municipality that owns or is responsible for the establishment or direction of a waste management system or a waste disposal site. The OWRC is neither a person nor a municipality.

Should the regulations of the Waste Management Act be deemed applicable to the disposal of all sewage sludge, it would make the task considerably more onerous than at present. Section 12 of the Act states that a disposal site must not be established, altered, extended or enlarged unless a certificate of approval has been issued by the Department. Section 18 of the Act requires that an applicant for a certificate of approval, publish notice of his application once a week for three successive weeks. Section 8 of the Regulations Made Under the Waste Management Act states that a certificate of approval expires one year after date of issue. The effect of this increase in "red-tape" will be to discourage future bidding for OWRC sludge disposal

contracts and to raise the amount of the bids received, without necessarily improving disposal methods or assuring public safety.

In summary it may be said that the present role of the Department of Energy & Resources Management concerning disposal of sludge, is ambiguous and requires clarification. Should the Department become directly involved, this will likely increase the costs of sludge disposal without necessarily improving disposal methods or assuring public safety. It is the opinion of the Division of Plant Operations that the disposal of sewage sludge be considered as an integral step in the treatment of sewage and that ultimate jurisdiction over its disposal be vested in the OWRC.

3.3.2.4 Department of Health

The Department of Health has traditionally shared the jurisdiction over sludge disposal with the OWRC, through the safeguarding of public health.

Section 82 of the Public Health Act defines a nuisance as "any condition existing in a locality that is or may become injurious or dangerous to health or that prevents or hinders or may prevent or hinder any manner the suppression of disease." Section1 (a) of the Air Pollution Control Act defines an air contaminant as "a solid, liquid, gas, odour or combination of any of them that contribute to air pollution" and section 1 (b) of the same Act states that air pollution "means the presence in the outdoor atmosphere of any air contaminant or contaminants in quantities that may cause discomfort to or endanger the health or safety of persons, ...". Thus disposal of sludge may create a nuisance or air contaminant as defined above. Section 89 of the Public Health Act and Section 9 of the Air Pollution Control Act give the Department of Health the power to prohibit the operation of the source of nuisance or air contaminant.

Section 7 of the Air Pollution Control Act requires that no person shall construct a stationary source of air pollution unless he has obtained a certificate of approval from the Department of Health. Although this section has not been enforced to date for OWRC sludge disposal sites, it appears to be applicable.

As in the case of the Waste Management Act, a minor technicality regarding the definition of 'owner" in both the Public Health Act (Section 1 (q)) and the Air Pollution Control Act (Section 1 (i)), would appear to exclude sludge disposal from the regulations of the Acts if the OWRC owned the disposal site. The definition of owner given in both cases does not include a body such as the OWRC.

The OWRC's contact with the Department of Health regarding sludge disposal generally comes through the local Medical Officer of Health (M. O. H). Sludge disposal contracts for OWRC operated plants require the contractor to meet the requirements of the M. O. H. In the case of sludge disposal in one County (Waterloo) the M. O. H. is informed monthly by the Division of Plant Operations of the location of the sludge disposal sites used and of any unusual conditions encountered.

It is expected that the OWRC and the Department of Health will continue to share jurisdiction over the disposal of sludge. The medically oriented function of the Department of Health is a desirable adjunct to the technically oriented function of the OWRC for the proper serving of the public interest.

3.3.2.5 Department of Municipal Affairs

The Department of Municipal Affairs exerts its influence on sludge disposal primarily through the Ontario Municipal Board and its Community Planning Branch.

The OMB in addition to its power to assess the financial soundness of municipal undertakings, may assume the role of arbitrator in disputes involving municipalities. Section 348 of the Municipal Act states that municipal councils may by by-law, designate the OMB the sole arbitrator. Hence in the case of refusal of a neighbouring municipality to allow disposal of sludge from another municipality, the municipality generating the sludge could designate the OMB as arbitrator. This matter is dealt with more specifically in Section 18 (5) of Bill 155, an Act to ammend the Municipal Act. Here it is stated that when a municipality wishes to dispose of its garbage, ashes and "other refuse" in another municipality and cannot reach agreement with that municipality, then it may seek the approval of the OMB. The OMB may then hold a public hearing and pass final judgement.

Although piping of sludge to disposal sites has not yet been practised at OWRC plants, Section 83 of the Municipal Act may be invoked when piping becomes a reality. This section states that the OMB (if called upon) may arbitrate in disputes involving the transportation of sewage from one municipality into or through another one by sewer. The OMB can "determine not only the terms and conditions upon which the extension or connection is to be made, but also the location of the sewage farm, filtering plant, or artificial means of sewage disposal that is contemplated, and whether the extension or connection should be allowed to be made."

In cases where sludge is generated in OWRC owned sewage plants as opposed to a municipally owned one, Section 17 of the OWRC Act gives the OWRC the same power to appeal to the OMB for arbitration. Section 17 states that the OWRC may for its purposes exercise any or all of the powers that are conferred by any general Act upon a municipality respecting the establishment, construction, maintenance, or operation of water works or sewage works.

Section 2 of the Planning Act empowers the Department of Municipal Affairs to define and name a "planning area" which may include part or all of one or more municipality. In defining the scope of an official plan, drainage, land uses, communications and public services are included. The adoption of an official plan is contingent on the approval of the municipalities involved and the Department and these municipalities appoint the planning board members subject to the approval of the Department. The Department is hence able to exert considerable influence on the land use in the planning area and hence on the disposal of sludge from sewage plants within the area.

In summary, it may be said that the Department of Municipal Affairs becomes involved in sludge disposal indirectly through its influence on land use in "planning areas" or directly when, as a last resort, it is called upon to arbitrate in a dispute concerning sludge disposal.

3.3.2.6 Others

There are a number of Provincial and Federal governmental bodies which enter into the jurisdictional problem regarding sewage sludge disposal. Contact with these bodies has been minimal to date, but it would appear that their participation will be inevitable in some cases.

The Department of Lands and Forests become involved in sludge disposal if the sludge is to be disposed of on public lands. Section 16 (1) of the Public Lands Act states that "the Minister of the Department of Lands and Forests may designate any area in territory without municipal organization as a restricted area, and he may issue permits for the erection of buildings or structures or the making of improvements on lands in any such area on such terms and conditions in any case as he deems proper." Since public lands in Ontario are primarily in the northern part of the province, it is plants in the north that may have their sludge disposal plans affected by the Department of Lands and Forests.

It is expected that the Department of Agriculture would become involved with sludge disposal in cases where the sludge was deposited on agricultural land used for the purpose of cultivating crops for either human or animal consumption. There have been informal contacts made between the Department of Agriculture and the Division of Plant Operations but no formal contacts have been made on either side. It is suggested that the Department's participation, in an advisory capacity, would be of great value. The experience of its Soils and Crops Branch of the Division of Production and Rural Development would be of value in assessing for various crops, the sludge application rates for optimum soil fertilization, conditioning and irrigation. Also the establishing of desirable limits for toxic materials in sludge and soil would be best determined in co-operation with the Soils and Crops Branch.

3.3.3 Public Relations

Contact with the public regarding sludge disposal at OWRC operated plants, has in the past been confined primarily to individuals who were directly involved in the disposal operation such as sludge hauling contractors, owners of land used for disposal and neighbours of these land owners. As the problems associated with sludge disposal and environmental pollution in general grow more acute, the press and organized groups such as Pollution Probe, the Federation of Ontario Naturalists, G.A.S.P. and the Canadian Association on Human Environment, will enter the picture. With the exception of the press and organized groups, contact with the public frequently is made via the local M.O.H.

In many instances, complaints from the public have been the result of poor sludge disposal practises on the part of sludge hauling contractors. The most common complaint is contamination of surface watercourses and subsequent destruction of aquatic wildlife, due to depositing of sludge too close to a surface watercourse, on land with poor assimilative properties, or during times of spring run-off or heavy precipitation. This type of blunder is undoubtedly greatly

aggravating to the public in view of the previous large expenditure of public funds to remove the sludge solids from raw sewage at the sewage treatment plant in order to prevent their entry into these same surface waters. Surface water contamination can be prevented by proper choice of disposal site and by proper supervision of disposal.

Another frequent complaint from the public is that of unpleasant odour from sludge disposal sites. This is usually the result of incomplete sludge digestion at the sewage plant. In cases where raw primary sludge has had to be hauled, this has nearly always resulted in odour complaints. This problem can be eliminated by thorough sludge digestion (either aerobic or anaerobic) and this is the responsibility of the plant operating personnel. However, choice of disposal sites remote from human habitation is obviously desirable.

Public complaints can arise out of purely aesthetic reasons. This is generally due to a misconception regarding the nature of sludge in that the sludge is thought of as being akin to untreated human faeces or livestock manure. Hence there is a natural aversion to the depositing of this sludge in any uncovered or unenclosed location. Properly digested sludge does not however bear any resemblance either in appearance or odour to the aforementioned wastes. Such complaints can only be overcome by a public education program.

3.4 Problems at Specific OWRC Operated Plants

The following is a list of plants which have experienced significant problems with disposal of their sludge in recent years.

CORNWALL

- 1st disposal site was City of Cornwall's sanitary landfill site. (September 1969)

- complaints received from Department of Energy Resources Management regarding contamination of surface water and new site recommended in September, 1969.

- sludge deposited in future in a contained part of the site as temporary expedient.

- new site on Ontario Hydro property approved by Department of Energy and Resources Management, Department of Health and OWRC but turned down by Ontario Hydro.

- sludge contractor found new dumping site in Township of Charlottenberg but Township passed prohibiting by-law.

- by-law later amended in May, 1970 to allow dumping in lagoon constructed by hauler.

- Department of Energy and Resources Management imposed its standards on disposal site.

FORT FRANCES

- local municipality has apparently restricted sludge disposal to dumping at municipal sanitary landfill site.

POINT EDWARD and MOORE TOWNSHIP

- restrictions imposed on sludge contractor by M. O. H. in 1970 became too onerous for dumping on privately owned land.

- contractor now dumps sludge at City of Sarnia's sludge lagoons.

SAULT STE. MARIE

- some consternation created by Department of Energy and Resources Management's directive to sludge contractor in October, 1970, to place vacuum filtered sludge in a drying lagoon before taking it to City dump.

- directive due to misunderstanding on part of Department of Energy and Resources Management and situation now back to normal.

THUNDER BAY - (North and South)

-incompetent sludge contractor disposed of sludge on his land in such a way as to arouse public outrage concerning odours and to be convicted of contravening a Township of Paipoonge by-law which regulates sludge application on land.

- OWRC received adverse publicity in press for itself and for sludge disposal in general.

- new contractor who disposes of sludge by dumping in abandoned quarry, was engaged December, 1969 and no further incidents have occurred.

TIMMINS

- M. O. H. received complaints re: escape of sludge in July 1970 from dumping site (Town of Timmins dump) into adjacent creek.

- contractor directed to dispose of sludge in a part of the dump remote from creek.

BURLINGTON - (Drury Lane, Elizabeth Gardens & Skyway)

- Town of Burlington passed restrictive by-law re: sludge disposal in June, 1966.

- inspection of land application site by plant staff in December 1970 revealed poor spreading of sludge and subsequent contamination of Shore Acres Creek.

- contractor was warned of his negligence and site inspection by plant staff was intensified.

CHATHAM

- M. O. H. received a number of complaints in 1969 re: disposal of sludge by land application and issued directives to sludge contractor on where to dump and requested he construct a temporary storage lagoon.

- during 1970 Townships of Raleigh, Harwich and Dover passed restrictive by-laws re: disposal of sludge.

- new sludge hauler has been forced to dispose of sludge by dumping at the Chatham sanitary landfill site.

GALT and PRESTON

- Township of North Dumfries passed a by-law in October 1970 prohibiting import of sludge into the Township without special permission of Council, apparently on the advice of the Department of Energy and Resources Management.

GEORGETOWN

- odour problems have occurred with the disposing of raw sludge on farm land in Township of Esquesing, and MOH and Department of Energy and Resources have prohibited disposal. (Raw sludge is being disposed of temporarily until digester repairs are complete).

- agreement is presently being sought with MOH and Department of Energy and Resources for a new site and improved site management techniques for this temporary problem.

HUNTSVILLE

-MOH has disallowed disposal of sludge by land application on agricultural land

NORTH BAY

- MOH received several complaints from adjacent landowners and Township of North Himsworth in March 1970 re: odours from disposing of sludge at a dump.

- a new site was found and approved by MOH.

PICKERING

- Township of Whitby threatened to prohibit disposal of sludge from Pickering in Township but did not follow through.

SOUTH PEEL

- In July, 1969 a complaint arose re: disposal of sludge by land application which allegedly destroyed some wildfowl on the property. Incident was covered by press and OWRC received bad publicity despite the fact that it was legally not responsible.

- In April, 1970, plant staff reported contamination of surface water courses with run-off from field used for land application of sludge.

- In November, 1970, a break occurred in a dyke at the "Meadowvale" lagoon used to dump sludge and caused sludge to escape and almost reach a surface water course.

- Sludge contractor was directed to construct a dyke around the spill and repair the old dyke.

- Spill was brought to attention of Town of Mississauga Council who passed resolution in November, 1970 prohibiting disposal of sludge by dumping in lagoons.

- Dumping ceased at the site and Town was placated temporarily.

- Department of Energy and Resources Management threatened to prohibit dumping in lagoons in Mississauga if sludge contractor did not comply with its directives.

- In January, 1971 sludge disposal by land application caused contamination of surface water course.

WATERLOO

- In April, 1970 plant staff received complaint of pollution of an adjacent surface water course due to run-off from "Reist" farm used for land application of sludge.

- Sludge disposal stopped at this site and dykes constructed to contain run-off.

4 PREDICTED FUTURE SLUDGE DISPOSAL PROBLEMS

4.1 Population Trends

Population increases will result in greater volumes of sludge to be disposed of, fewer areas available for disposal close to treatment plants, and a greater need to recycle the material for agricultural purposes.

In order to predict the increase in sludge volume to be disposed of it was assumed that the increase would be proportional to the growth of urban population in the province. In 1969, the population in Ontario urban communities (cities, towns and villages) was approximately 5,730,000. From information received from the Regional Services Planning Branch of the Division of Sanitary Engineering (43) based on the statistics from the Ontario Department of Treasury and Economics and Department of Municipal Affairs, it appears that the Ontario population in urban communities in 1981 will be in the order of 8,100,000. This represents an increase of about 41%. Hence an increase in sludge production of 41% can be expected between 1969 and 1981. This increase assumes that the sludge disposed of is of the same average solids content but if the trend is to less dewatering of sludge there would be a further increase in volume. Also the 41% increase does not take into account changing technology in sewage treatment (e.g., phosphorus removal), domestic trends (e.g., use of garbage grinders) or industrial trends (e.g., reliance on municipal treatment facilities rather than their own) which would increase sludge volumes.

Balakishnan et/al (58) suggest that the volume of sludge to be disposed of will increase 60 to 70% within the next 15 years, due both to increase in population and in the degree of sewage treatment.

As urban communities grow in size, they do so at the expense of land available for disposal of sludge close to treatment plants. Although it is predicted that there will be a greater acceptance of sludge disposal by land application and hence an increase in the land area available (private or public), these sites will be further removed from the sources of the sludge. This will make sludge transportation by truck increasingly difficult particularly for large urban centres (cities and large towns). Hence for these centres an alternative means of transportation will be necessary if disposal by land application or dumping is to be used. Transportation by pipeline appears to have the most promise. Because of the economic problems of sludge transportation there will be an increasing drive on the part of some to use disposal by incineration.

The total population of Ontario is expected to increase about 28% from the 1969 total of 7,080,000 to 9,050,000 in 1981 (43). The majority of this growth is likely to occur in southern Ontario. Hence there will be an intensification of farming of the arable land in southern Ontario which has been and likely will continue to be a major source of food for the whole province. One many farms, fertilizers are already one of the major costs in crop production (32). Although by no means a "cure-all" for the problems of intensive farming, the soil fertilizing conditioning and irrigating properties of sewage sludges produced in Ontario sould contribute significantly to the solution of these problems.

4.2 Phosphorus Removal

4.2.1 General

The consequences of the proposed phosphorus removal program for Ontario municipal sewage plants will apparently have a profound affect on sludge disposal. This is due to the fact that current phosphorus removal processes seriously affect both the quantity and quality of sludge produced in a sewage treatment plant.

The OWRC is presently proposing the following phosphorus removal program (29).

i) Plants with capacities of 1.0 IMGD and larger located in the Lake Erie drainage basin, certain portions of Lake Huron, the Ottawa River system and inland waters will require phosphorus removal facilities (for 80% removal of total phosphorus) by December 31, 1973, and those located in the Lake Ontario basin by December 31, 1975.

ii) Plants smaller than 1.0 IMGD will require phosphorus removal, where discharge has created local nuisance conditions, in the same designated areas and with target dates as in (i).

It should be noted however that there is a continuing controversy over the desireability or feasibility of eliminating phosphorus from certain bodies of water (30), (52), (53), and this may curtail phosphorus removal programmes in some areas.

In preparation for this program a number of temporary experimental studies have been and are being carried out by the Division of Research in conjunction with the Division of Plant Operations and the Division of Sanitary Engineering. Included in these studies are the Sault Ste. Marie, Richmond Hill, Newmarket, Preston, Elmira, Markham and Stratford projects. The Dow Chemical Company has performed tests at the Lakeview plant. However the studies to date have been primarily concerned with the most efficient means of removing phosphorus from sewage, and not with the problem of what to do with the phosphorus once removed.

The phosphorus removal processes which will influence the sludge disposal problem the most are those using chemical precipitation of the phosphorus within the primary and secondary treatment facilities of the treatment plant. Here the precipitated phosphorus will end up as an intimate part of the regular sludge removed from the primary and secondary clarifier. Phosphorus removal processes which treat the effluent from the treatment plant (tertiary treatment) will extract the phosphorus in such a way that it could be kept separate from the regular sludge removed from the sewage, and disposed of separately. A solids disposal problem will be created but there may be relatively small volumes involved and the purity of these solids should enable recycling or reuse of part of these solids. Mulbarger et/al (36) report that lime treatment of secondary effluents produces a sludge which can be recovered and reused for its lime content and also as an agricultural fertilizer.

Hence the remainder of this section will deal with phosphorus removal within the primary and secondary facilities of a plant by means of chemical addition. The chemicals currently favoured for this use are iron or aluminum salts or lime. Organic polyelectrolytes may also be used as flocculation aids.

4.2.2 Sludge Volumes

With regard to lime precipitation of phosphorus Schmid and McKinney (4) state that the sludge produced from the primary clarifier can be expected to be about twice that obtained by conventional settling. When sludge quantities are compared to the overall system including the waste activated sludge the lime treatment results in a total sludge production less than 1.5 times the conventional system.

These predictions involve the use of 150 mg/l $Ca(OH)_2$ which together with the biological system is claimed to be capable of removing 90 to 95% of the total P from a domestic wastewater containing 40 to 50 mg/l PO_4. Buzzell and Sawyer (34) found that the volume of sludge produced from lime treatment of raw sewage was approximately 1.0% of the volume of sewage treated (80 to 90% total P removals achieved). Using lime dosages of about 175 mg/l, Black and Lewandowski (37) determined that the sludge drawn off the primary clarifier during lime treatment was less in total volume than that produced by conventional treatment (92% reduction in total P achieved in primary and secondary section). The sludge drawn off the primary clarifier had a total solids concentration of 6.0 to 8.0%.

The volume of sludge appears to be determined by the extent of precipitation of the carbonate in the sewage with greater carbonate precipitation resulting in a more settleable sludge and hence a sludge of lesser volume. This would seem to account for the large volumes for Schmid & McKinney's gelatinous sludge with little $CaCO_3$ content and Black and Lewandowski's "free flowing" sludge which apparently contained considerably more $CaCO_3$. The extent of carbonate precipitation is affected by the pH of the reaction (amount of lime added) and the phosphate concentration in the sewage (4).

With regard to sludge volumes produced by precipitation of phosphorus with alum, Eberhart & Nesbitt (31) report that when alum was added to the aeration tank effluent, the waste activated sludge production was less by volume and greater by weight, than that from a comparable untreated system. Alum dosage of 335 mg/l resulted in 30% less waste activated sludge by volume. In contrast with this finding, Zenz and Pivnicka (56) reported that when feeding alum in the range of 100 to 250 mg/l, the volume of waste activated sludge was consistently greater than that from a comparable untreated system. This occurred despite a much lower sludge volume index associated with higher alum concentrations.

In considering the foregoing studies it should be remembered that the authors were dealing with sludge produced in the final clarifiers only, as the location of alum feed was after the aeration tanks. Hence their findings pertain only to that portion of the total sludge volume, composed of waste activated sludge.

Thomas (35) found that phosphorus precipitation with ferric chloride did not result in increased sludge volumes (90% P removals achieved). The Dow Chemical Company (40) conducted tests of several Michigan sewage plants with ferric chloride and reported that a modest reduction in overall sludge handling costs could be expected (total phosphorus removal averaged 72 to 87%). Although some additional inorganic solids were being produced in the process the reduction of secondary sludge due to improved primary sedimentation efficiency represented a real cost savings in terms of digester volume and dewatering costs. Dow found that at the Lakeview plant 25 mg/l ferric iron and 0.5 mg/l polymer produced 80% reduction in total P, and at the Pontiac, Michigan plant 15 mg/l ferric iron and .2 to .3 mg/l polymer yielded 84 to 89% reduction in total phosphorus (41).

4.2.3 Sludge Characteristics

In addition to sludge volumes the characteristics of the sludge produced by phosphorus removal are important. This is particularly true if the sludge is to be disposed of by land application. With regard to lime treatment Schmid & McKinney (4) state that this sludge is not the typical "lime sludge" but is instead a sludge with properties more like the gelatinous hydroxide precipitate of the other metal coagulants. They further state that lime regeneration is not desireable, for calcium carbonate is the only form from which the lime can be recovered, and calcium carbonate is not precipitated to a significant degree. The sludge produced was reportedly hard to dewater by itself. The mixture of lime precipitated primary sludge and waste activated sludge dewatered and filtered well with relatively small additions of anionic polymers.

Studies by Black & Lewandowski (37) resulted in a lime sludge that was not a gelatious type sludge but rather it was free flowing. Although it readily settled to a concentration of 10 to 12% solids, it was very difficult to dewater. The sludge was stablized by the high concentrations of lime and was free from noxious odours even after prolonged holding under anaerobic conditions. All sludge precipitated was a mixture of calcium phosphate, calcium hydroxide, calcium carbonate, coagulated organics and grit. Schmid & McKinney (4) and Mulbarger et/al (36) state that phosphate precipitated with lime actually produced a hydroxyapatite with a base formula of $Ca_5(OH)(PO_4)_3$.

Although information on the pH of actual lime sludges is not available Black & Lewandowski (37) state that the primary effluent pH averaged 9.2. Mulbarger et/al (36) state that at a reaction pH of 9.5 essentially all the phosphate should be precipitated as hydroxyapatite.

Most of the phosphorus removed by lime precipitation will be in the relatively insoluble calcium phosphate or hydroxyapatite form although some organic phosphorus and polyphosphates will be absorbed or adsorbed by the settling floc (4).

With regard to phosphorus precipitated by iron salts the resultant precipitate has been described as an iron phosphate, $FePO_4$, and an iron hydroxo complex (38). The optimum pH for the precipitation reaction is reported to be 5.0 (31) but good results have been achieved at pH 7.1 (38). The pH of the sludge itself is thus likely to be neutral or slightly acidic. The phosphate precipitated by iron salts is believed to be relatively insoluble and would not be appreciably released by anaerobic digestion (38). However, the sludge will contain some organic phosphorus and polyphosphates which would not be bound in this precipitate

form. Stabilization of organic matter and destruction of pathogenic organisms is not believed to be significant.

The use of aluminum salts for precipitation of phosphorus produces a precipitate which is thought to be aluminum phosphate, $AlPO_4$, or an aluminum hydroxo complex (38). The optimum pH for the precipitation reaction is reported to be 6.0 (31) however lower reaction pH's have been used (38). Hence as in the case of iron salts, phosphorus removal by aluminum salts should produce a slightly acidic sludge. The solubility of the phosphorus in the sludge would be similar to that for iron salt precipitation (52), (56) as would the degree of sludge stabilization and pathogen destruction. By using sodium aluminate as opposed to other precipitants, Barth and Ettlinger (51) note that extraneous sulphate, chloride and calcium is eliminated.

4.2.4 Effects on Ultimate Sludge Disposal

Regarding sludge disposal by dumping, it is apparent that phosphorus removal by lime precipitation will considerably increase the total sludge solids to be disposed of. The increase in volume is somewhat less predictable depending apparently on the extent of carbonate precipitation. It would see prudent however to anticipate double the sludge volume from primary plants and 1.5 times the sludge from secondary plants and a commensurate increase in sludge transportation costs as a result. There will be an increase in the rate at which the dump site capacity is consumed, proportional to the increase in total sludge solids to be disposed of. In addition the use of lime appears to result in deposits of $CaCO_3$ scale (37). This will undoubtedly adversely affect sludge transportation by pumping.

Precipitation by iron and aluminum salts on the other hand likely will not result in significantly increased sludge volumes although total sludge solids will increase considerably. The increase in total sludge solids in the case of precipitation with iron or aluminum salts appear to be less than with lime.

There is concern over the long term stability of the phosphorus precipitates formed by iron and aluminum salts and lime (38) (37). Under lowered pH conditions there could be leaching of phosphorus from a dump site used for sludge disposal.

In connection with sludge disposal by incineration there is some controversy as to whether phosphorus precipitation, particularly with lime, precludes this form of sludge disposal. Albertson & Sherwood (42) state that both laboratory and commercial tests establish the fact that combustion of lime mud with wastewater sludge is practical and that calcium oxide can be recovered from the combustion ash. Schmid & McKinney (4) however state that lime regeneration is not desirable because calcium carbonate is the only form from which the lime can be recovered, and calcium carbonate is not precipitated to a significant degree.

Apart from the practicality of recovery of the precipitant, phosphorus removal will increase the cost of auxilliary fuel requirements for incineration. This is due to the reduction in the concentration of organic matter in the sludge caused by the inclusion of the inorganic precipitates and also to the heat consumed by the calcination of the precipitates. Calcination of lime and ferric chloride are reported to require 388 and 63 BTU/lb. respectively (6). Data published by Dorr-Oliver Inc., (6) indicates that a reduction of approximately 6% in the volatile content of sludge results in a 50% increase in auxilliary fuel cost per ton of dry sludge solids.

Another problem with incinerating lime sludges is indicated by the reported buildup of lime from sludge conditioning prior to vacuum filtration on incineration walls at the Denver plant (46). When the three inch to four inch thick scale falls off the wall, minor explosions occurred. Also the lime plugged grids in the incinerator scrubber.

Disposal of sludge by land application may also be adversely affected. This is particulary true for land which was to be used for repetitive as opposed to infrequent sludge disposal. The comments regarding effects of phosphorus removal on transportation costs for disposal by dumping, will apply to disposal by land application too. More important however is the effects on the soil fertilizing and conditioning properties of the sludge. The effect of the lime sludge on the soil pH would appear to be detrimental. In general, most crops grow satisfactorily and plant nutrients are readily available when the soil pH is 6.0 to 7.0 (32). The tolerable pH will depend on the crop planted but will be in the range of 5.5 to 8.5. It appears that the pH of phosphorus sludge will be greater than 9.5 for lime, and neutral or slightly acidic for iron and aluminum salts. Hence some restrictions would be necessary for lime sludge at least, depending on the pH of the soil used and the crops grown. However for infrequent sludge application the judicious application of a high pH sludge to a low pH soil or visa versa could improve soil fertility.

Another problem created by the addition of lime, iron or aluminum precipitates to soil will be that of a build-up of calcium, iron or aluminum in the soil. Although these elements will be bound in a relatively insoluble compound there is likely to be some limit at which their concentration becomes toxic to certain crops. Compared to aluminum and iron, about 4 to 6 times as much calcium would be required, for phosphorus removal. However the requirement of plants for calcium is about twenty times that for iron, while aluminum has not been shown to be required for growth at all (32).

The phosphorus removed during chemical precipitation is in a relatively insoluble form and would be released in only small quantities within the pH range necessary for plant growth (about 5.5 to 8.5). Thus it will be of reduced value for soil fertilizing. Tri-calcium phosphate is not soluble in water but is dissolved by many naturally occurring soil acids, a process which releases the phosphorus in forms usable by plants (32). In acid soils (pH less than 6.5) iron phosphate is virtually unavailable to plants. Also unreacted precipitant could conceivably combine with dissolved phosphate already in the soil. It is not known what portion of the original sludge phosphorus content will become chemically bound but there will always be some organic phosphorus remaining.

A benefit that may be provided by phosphorus removal is the reaction with heavy metals such as copper, boron and zinc in the sludge thereby producing a relatively insoluble precipitate and reducing the uptake of these elements by the crop (39).

In connection with lime precipitation of phosphorus there may be some additional advantages besides precipitating undesired sludge components and raising the soil pH (of acid soils). Vankleek (10) states that lime encourages the bacterial decomposition of organic solids thereby increasing the effectiveness of sewage sludges. It improves the physical structure of heavy soils and supplies the necessary element calcium. He states that lime makes phosphorus more available, although this appears questionable to the writer in the light of recent findings on phosphorus precipitation with lime. He recommended that .5 to 1.0 ton of lime per acre be applied in the fall before the use of fertilizers. It is stated that the continued use of any type of sludge unless previously conditioned with lime requires the periodic addition of lime to the soil to prevent harmful acidity (39).

In summary it may be said that the problems of ultimate disposal of sludge from phosphorus removal processes within the primary and secondary processes of a sewage plant, are very uncertain to date due to the lack of research in this regard. This is particulary true for disposal of sludge by land application. It would appear that the regular application of phosphorus sludge to land may be seriously curtailed due to the creation of adverse growing conditions for crops. This will increase the area of land required for this method and may make the method impractical. Lime precipitation appears to present the greatest difficulties due to the high pH of the sludge and the larger quantities of sludge to be disposed of.

4.3 Public Reaction to Sludge Disposal

There is an unprecedented awareness on the part of the public at large regarding problems of the environment including the various types of pollution, population control, recycling wastes, conservation or resources etc. Although sludge disposal per se., has not achieved great distinction, it has considerable potential. It is suggested that any form of sludge disposal which fails to utilize the valuable properties of the sludge and prevent degradation of the area in which it is disposed of, will be the subject of considerable public criticism in the future. The disposal method which can best accomplish these objectives at present is that of land application.

Among the Sanitary Engineering profession there is a growing attention being paid to ultimate sludge disposal. The literature dealing with this topic as reviewed in the annual literature review of the Journal of the Water Pollution Control Federation gives some indication of the trend. The following is a count of the papers and reports dealing with the ultimate disposal of municipal sewage sludge during the past three years.

DISPOSAL METHOD	1968	1969	1970
Incineration	11	15	16
Land Application	5	15	20
Dumping *	4	3	3

* Literature primarily deals with disposal of sludge from coastal cities, at sea.

Based on a survey of U.S. consulting engineers conducted in 1968, Balakrishnan et/al (58) reported that the overall attitude of the consultants was acceptance and even eagerness to employ incineration. Sixty-five percent believed incineration use was increasing, 6.% believed it was decreasing and 29.% had no opinion.

Although the trend is to a greater interest in disposal of sludge by land application, it is expected that many sanitary engineers will remain proponents of incineration, particularly for the larger communities. Without maligning the consulting engineer in any way, it should be noted that it is perhaps to be expected that a consultant at present would favour incineration over other methods, due to the fact that considerably more information is available regarding this method and due to the fact that there is a greater potential for design work.

With regard to the agricultural community and the disposal of sludge by land application, it is anticipated that the major problem will be one of communications. This knowledge regarding the agricultural value of sludge must be widely circulated and in a convincing manner among farmers. It would appear that the Provincial body with the most capability for this job will be the Department of Agriculture and Food. Hence a good liaison must be established between the OWRC (or whichever body acquires control over ultimate sludge disposal) and the Department of Agriculture and Food.

It is expected that future problem with municipal officials will also centre around good communications. Once these officials have been given the necessary facts regarding a particular sludge disposal method, it is likely that the passage of restrictive municipal by-laws will be eliminated. The communications problem will also rest with the provincial body which has ultimate control over sludge disposal.

5 SUMMARY and RECOMMENDATIONS

The foregoing sections of this report were intended to illustrate that ultimate sludge disposal in Ontario is a costly and troublesome aspect of sewage treatment, that the magnitude of the costs and the severity of the problems are on the increase and that the time is ripe for the OWRC to undertake remedial measures. The following are recommendations for specification on the part of the OWRC.

a) Settlement of Jurisdictional Disputes

Before the problems of sludge disposal can be efficiently solved there must be a clear delineation of jurisdiction with respect to the various provincial bodies currently involved. It is the opinion of the Division of Plant Operations that the OWRC should have ultimate jurisdiction over sludge disposal. This opinion is based on the fact that the OWRC already has jurisdiction over all the sewage treatment facilities which determine the characteristics of the sludge as well as its total amount and rate of generation. It is therefore the logical body to control the ultimate disposal of this material. In addition there is considerable evidence in the pertinent Provincial statutes to indicate that the OWRC should be the ultimate authority with regard to sludge disposal.

It is to be hoped that other Provincial bodies (notably the Department of Energy & Resources Management) will acknowledge the OWRC's precendence regarding sludge disposal on the strength of the logical and legal arguments noted in this report. If negotiations with these bodies fail to reach this conclusion, then it is recommended that the OWRC take the matter to the Minister of Energy and Resources Management for arbitration.

A major reason for the encroachment of other Provincial bodies on the jurisdiction of the OWRC is the OWRC's failure to exercise proper control over sludge disposal in the past. The recommendations listed hereafter should reverse this trend if implemented.

b) Policy Regarding Preferred Disposal Method

It is recommended that the OWRC adopt a policy favouring the disposal of municipal sewage sludge by land application. While recognizing that this method is not without difficulties and is in a relatively unsophisticated stage in its development it is believed that there is sufficient evidence, both from the economic and the ecological standpoint, to warrant this preference.

Costs for land application taken from the literature appear to favour this method over incineration. Costs at OWRC operated plants for land application appear to be similar to those from the literature. Also the development of sludge transportation by pipeline, promises to reduce one of the major sources of cost for land application for larger communities. Land application is the method which best overcomes the two major problems of pollution of the environment and wastage of valuable sludge properties.

Preference to this method should not take the form of immediate prohibition of all others but should increase in relation to the findings of research into the techniques and environmental effects of land application (see recommendation "g"). Furthermore, the use of conservative application rates should be advocated initially until the effects of a particular sludge on the environment are established.

c) Development of Nutrient Removal Processes

The development of nutrient removal processes must include a greater emphasis on the problem of ultimate disposal of the nutrients removed. The current phosphorus removal studies underway in Ontario have the potential for disrupting or prohibiting conventional methods of sludge disposal particularly the method of land application. It is suggested that one of the criteria for acceptance of a phosphorus removal process be that it must not impair the soil fertilizing or conditioning property of the sludge normally produced at a sewage plant. If studies indicate that the removal of phosphorus within the primary and secondary facilities impairs the sludge quality severely then phosphorus removal by tertiary treatment could be substituted, and the resultant sludge kept separate from the primary and secondary sludge.

It is necessary that this recommendation be dealt with as soon as possible due to the commitments the OWRC has made to have phosphorus removal processes in certain plants as early as 1973.

d) Inclusion of Sludge Disposal in Plant Designs

It is recommended that the OWRC insist that the design of all new plants or of major extensions to existing ones, incorporate the method of ultimate sludge disposal to be used. It is no longer reasonable to concentrate all efforts on removing the pollutants from sewage without determining what is to be done with them once removed.

In the case of sludge disposal by land application the consultant should be requested to provide the following information for his alternatives:

i) method of transporting sludge (including a study of dewatering possibilities) with estimated capital and operating costs.

ii) estimated quantity and characteristics of the sludge.

iii) availability of disposal sites with respect to topography, soil characteristics, surface water courses, population density, and proximity to the sewage plant.

iv) recommended sludge application rates and land area requirements.

v) sludge storage recommendations at plant and in the field and the capital and operating costs of same.

vi) the feasibility of purchasing or leasing part or all of the disposal site requirements.

vii) where actual disposal sites can be chosen, the required modifications to the site should be given as well as their capital costs.

e) Public Relations

It is suggested that some form of public relations effort be undertaken by the OWRC regarding sludge disposal, and embodying the principles outlined in part (b) of this section. The three general groups that should be reached are municipal officials, the agricultural community and the general public.

With regard to municipal officials, the effort should be directed towards making them sympathetic towards the problems of disposal of sludge from municipal sewage plants. The available methods of disposing of sludge should be reviewed with the purpose of illustrating that certain municipal by-laws may preclude desirable methods of disposal. The innocuous nature of digested sludge should be emphasized as well as its agricultural value, when properly disposed of. Also, the symbiotic relationship which must exist between urban and rural communities and hence the obligation which the rural community has, to assist in the disposal of sludge, should be stressed. It should be suggested that the OWRC be consulted when problems arise from sludge disposal and before bylaws concerning sludge disposal are enacted.

It is recommended that the agricultural community be approached indirectly through the Department of Agriculture and Food. The Department's co-operation should be solicited for assistance in research regarding the disposal of sludge on agricultural land (see rec-recommendation (g)), and for dissemination of the known information on the soil fertilizing, conditioning and irrigation properties of sludge to farmers. This could be done through their regular publications and through their agricultural extension couses.

Some effort should be made to inform the general public of the work being done in the field of sludge disposal in order to eliminate misconceptions regarding the nature of digested sludge and to create a favourable attitude towards the recycling of this "waste" within the environment. Contact with the public could be made through the many organized groups which are oriented towards conservation and pollution control.

f) Supervision of Sludge Disposal

It is suggested that the present contract system employed by many OWRC operated plants for the disposal of sludge be amended to minimize repetition of past cases of unsatisfactory disposal. This type of situation not only results in detrimental effects on the environment but also invites intervention from other provincial bodies thereby encouraging jurisdictional problems and "red tape" conditions.

The present contract confers ownership of the sludge and the responsibility for its disposal, on the contractor. In most cases, the contractor is unaware of the properties of the sludge and of the proper means of disposing of it. In the future it is hoped that the sludge hauling contract will become only a contract for the transportation of a product from one point to another and that the ownership and responsibility for disposal would remain with the operating agency. However, at this stage of the development of sludge disposal practices, it may be in the interest of efficiency to confer the ownership and responsibility for disposal, on the contractor. The answer to the problem for the time being must therefore be increased supervision over the contractors' disposal activities.

In order to improve the present contract system, it is recommended that a set of general requirements for a sludge disposal site, be included in the contract conditions. This would enable the prospective contractor to submit along with his tender, a description of his proposed disposal site and any modifications or management practices required. Upon receipt of the bids, the proposals of the low bidder should be reviewed in the field preferably in the company of the bidder, the local M. O. H. and the representatives of any other group having authority and only after approval of all concerned has been obtained, should the contract be awarded.

It is suggested that no sludge hauling contracts be renewed in the winter due to the problems of adequately inspecting the disposal site at this time of year.

The sludge hauling contract should contain a clause allowing the operating agency to terminate the contract if the contractor fails to dispose of the sludge in an approved manner, as well as at an approved disposal site.

Regular inspection of the disposal site by the field and head office staff of the operating agency must be made. Records should be kept as to which disposal sites were in use and what volumes of sludge and what weights of sludge solids were disposed of at each site. Periodic soil sampling should be carried out. Monitoring of adjacent ground and/or surface waters should be included.

Conservative application rates should be enforced initially until the effects of the particular sludge on crops are well established. Staff of the Department of Agriculture and Food should be consulted in this regard.

g) Research Regarding Land Application

It is recommended that the OWRC undertake field and lab research into the disposal of sludge on agricultural land. Such work would be most conveniently conducted with OWRC operated plants. The work must include the services of the Department of Agriculture and Food. Research should be conducted on a variety of sludges including a "typical" anaerobic digested sludge, an anaerobic sludge with high heavy metal content, and sludges from plants employing phosphorus removal by precipitation with iron and aluminum salts and lime.

Lab studies are required to determine the tolerable concentrations of various sludge components for a variety of forage crops. Field studies are required to confirm the latter and to establish optimum criteria for disposal sites and their management, to investigate the effects of repeated disposal with regard to ground water contamination to assess the soil fertilizing, conditioning, and irrigation properties of sludge as related to crop yield and quality.

One site which appears suited for field tests is the 70-acre property owned by the City of Brantford, being used for disposal of sludge from the OWRC's Brantford Plant. Other sites that could be considered are those owned by sludge hauling contractors for OWRC operated plants such as Newmarket, Belleville and Burlington.

h) Control of Disposal Sites

It is suggested that in the future an alternative will be required for the present procedure of disposing of sludge on privately owned land without any formal agreement with the owner. This procedure does not give the operating agency of the sludge hauling contractor sufficient control or security with respect to the disposal operation. It is suggested that the following alternatives or combinations of them be considered, and given a trial at some existing plants over the period of the next two or three years.

i) OWRC lease privately owned agricultural land.

Terms of lease to give OWRC right to dispose of a prescribed amount of sludge on a continuous basis for one year and to carry out certain site management practises.

Owner to resume cultivation at the end of the year.

ii) OWRC and private land owner to sign a sludge disposal agreement for a two or three year period.

Terms of agreement to allow OWRC to dispose of a prescribed amount of sludge each year, in such a way as to not interfere with the concurrent cultivation of the land.

Terms of agreement to require that certain site management practices be carried out by the owner.

iii) OWRC to purchase agricultural land and make necessary modifications.

Sludge to be disposed of so that all or part of the land is always available for cultivation during the growing season, and would be leased to farmers for this purpose.

Lease would require farmer to cultivate the land for a specific time period (say two or three years) and for specific crops.

The success of such co-operative ventures between the operating agency and private concerns would depend greatly on the crop yields and quality and how these results were publicised. It is suggested that with favourable publicity there would be sufficient demand for sludge, to enable the operating agency to charge farmers for the sludge or its use and therby reduce or eliminate the cost of leasing or owning disposal sites.

i) Transportation of Sludge by Pipeline

It is recommended that the OWRC investigate the transporting of sludge by means of pipelines to determine its practicality as an alternative to trucking. A trial section of pipeline say, two to three miles in length, could be incorporated into the design of a new project or added to an existing one. Such a length of pipeline would not transport the sludge all the way to a disposal area but would be of value in assessing operating costs and problems to be expected for a full scale pipeline. An OWRC-operated plant should be considered for the trial, to facilitate the monitoring of the operation of the pipeline.

j) Urban Planning Considerations

It is recommended that the Community Planning Branch of the Department of Municipal Affairs be contacted regarding the problems of sludge disposal. It is essential that those controlling the nature of urban growth be informed and reminded of the problems created by certain forms of urban development, for the disposal of sludge and other solid wastes. There must be some limitations on the size and proximity of urban centers if the recycling of sludge and other solid wastes back to the environment is to remain practical in Ontario. Without the direction of future growth to less populated areas and without the maintenance of "greenbelts" around existing urban areas, this recycling which appears to be essential ultimately, will be made increasingly difficult.

6. REFERENCES

1. Andrews, R.H., "Sludge Treatment & Disposal", OWRC Publication No.23, January 1967.

2. Hinesly, T.D., & Sosewitz, B., "Digested Sludge Disposal on Crop Land", J.W.P.C.F., May 1969.

3. Dalton, F.E., Stein, J.E. and Lynam, B.T., "Land Reclamation - A Complete Solution of the Sludge Solids Disposal Problem", J.W.P.C.F., May 1968.

4. Schmid, L.A. & McKinney, R.E., "Phosphate Removal by a Lime-Biological Treatment Scheme", J.W.P.C.F., July 1969.

5. Quasim, S.R. & Burchinal, J.C., "Leaching from Simulated Landfills", J.W.P.C.F., March 1970.

6. Burd, R.S., "A Study of Sludge Handling & Disposal", Publication WP-20-4, U.S. Dept. of the Interior, May 1968.

7. Raynes, B.C., "Economic Transport of Digested Sludge Slurries", J.W.P.C.F., July 1970.

8. Chou, T.L., "Resistance of Sewage Sludge to Flow in Pipes", Proc. San. Eng. Div., A.S.C.E., September 1958.

9. Waste Management Branch, Ontario Dept. of Energy & Resources Management "Waste Management Branch - Comprehensive Plan" Issue 2, December 1967.

10. Vankleek, L.W., "Utilization of Sewage Sludge", Water & Sewage Works, Ref. Edition, 1953, (pp. R-203 to R.206).

11. Nusbaum, I. & Cook Jr. L., "Making Topsoil with Wet Sludge", Waste Engineering, pp.438-440, August 1960.

12. Thomas, R.E. & Bendixen, T.W., Degradation of Wastewater Organics in Soil", J.W.P.C.F., May 1969.

13. Le Riche, H.H., "Metal Contaimination of Soil in the Woburn Market - Garden Experiment Resulting from the Application of Sewage Sludge", Journal of Agric. Sci., Camb., 71, 1968.

14. Bechtel Corporation, "Technical Aspects of Pipelining of Waste Materials", F.W.P.C.A., Waste Management Study, 1969.

15. Quirk, T.P., "Sludge Concentration Filtration & Incineration", Continued Education Series No.113, University of Michigan, 1964.

16. Evans, J.O., "Ultimate Sludge Disposal & Soil Improvement", Water & Wastes Engineering, June 1969.

17. Schwartz, W.A. & Bendixen, T.W., "Soil Systems for Liquid Waste Treatment & Disposal : Environmental Factor", J.W.P.C.F., April 1970.

18. McLaren, J.W., "Evaluation of Sludge Treatment & Disposal", Canadian Municipal Utilities, May 1961.

19. Farvolden, R.N. & Hughes, G.M., "Hydrogeologic Factors in Landfill Design", Proced. Ont. Industrial Waste Conference, June 1969.

20. Millward, R.S. & Darby, W.A., "Sludge Disposal by Dewatering & Combustion", Water & Wastes Engineering, October 1967.

21. Anderson, R.V., "Sludge Incineration - The Argument For", Water & Pollution Control, July 1967.

22. Crawford, G.B. & McDonald, N.G., "Sludge Elutriation, Filtration & Incineration - Drying at Toronto", J.W.P.C.F., February 1966.

23. Alford, J.M., "Sludge Disposal Experiences at North Little Rock, Arkansas", J.W.P.C.F., February 1969.

24. Dean, K.C., Havers, R. & Valdez, E.G., "Utilization & Stablization of Solid Wastes", Proced. Ont. Industrial Wastes Conference, June 1969.

25. Anon., "Canada's Largest Sludge Incinerators Fired Up & Running", Water & Pollution Control, January 1969.

26. Jones, P.H., "Why the Modern Farm Handicaps Pollution Control", Water & Pollution Control, March 1969.

27. Can. Dept. of Agriculture, "Soil Erosion by Water", 1961.

28. Sebastian, F.P. & Cardinal, P.J., "Solid Waste Disposal", Chem. Engineering, 1968. (W.P.C.F. Lit review 1969, p.943).

29. OWRC Inter-Office Memo, J.R. Barr to D.S. Caverly, October 16, 1970.

30. King, D.L., "The Role of Carbon in Eutrophication", J.W.P.C.F., December 1970.

31. Eberhart, W.A. & Nesbitt, J.B., "Chemical Precipitation of Phosphorus in a High-Rate Activated Sludge System", J.W.P.C.F., July 1968.

32. Ont. Dept. of Agriculture, "Ontario Soils", Publication No.492, 1964.

33. Teng., W.C., "Foundation Design", Prentice Hall Inc., 1962.

34. Buzzell, J.C. & Sawyer, C.N., "Removal of Algal Nutrients from Raw Waste Water with Lime", J.W.P.C.F., October 1967.

35. Thomas, E.A., "Phosphate Elimination in the Activated Sludge Plant at Mannedorf & Phosphate Fixation in Lake & Sewage Sludge", Water Pollution Abs. (Brit.), 1966.

36. Mulbarger, M.C., Grossman, E., Dean, R.B. & Grant, O.L., "Lime Clarification, Recovery, Reuse & Sludge Dewatering Characteristics", J.W.P.C.F., December 1969.

37. Black, S.A. & Lewandowski, W., "Phosphorus Removal by Lime Addition to a Conventional Activated Sludge Plant", O.W.R.C. Research Publ. No.36, November 1969.

38. Nesbitt, J.B., "Phosphorus Removal - The State of the Art", J.W.P.C.F., May 1969.

39. Vankleek, L.W., "Fertilizer Value in Waste Disposal Methods", Amer. Journ. Public Health, March 1954.

40. Dow Chemical Co. of Canada Ltd., "The Dow Process for Phosphate Removal", 1970.

41. Hennessy, I., Jelinski, R., Beeghly, J.H. & Pawlak, T.J., "Phosphorus Removal at Pontiac, Michigan", Dow Chemical Co.

42. Albertson,O.E. & Sherwood, R.J., "Phosphate Extraction Process", J.W.P.C.F., August 1969.

43. Correspondence between C.E. McIntyre, Division of Sanitary Engineering & R.M. Bell, Division of Plant Operations, January 14, 1971.

44. Noering, F., et al. "Breakdown of Pollutants in Ground Water Beneath Waste Deposits", Chem. Abstracts, 68,72019, 1968.

45. "Land Requirements for Utilization of Liquid Manure in Crop Production", Ont. Dept. of Agriculture & Food, Information Leaflet, Agdex 5-38.

46. Kifer, D.L., "Start-Up at a Metropolitan District Plant", J.W.P.C.F., July 1968.

47. Bucksteeg, W., "Disposal of Inorganic Contaminants, Requirements & their Fulfillment", Chemical Abstracts, 68,33010, 1968.

48. Harris, S.M., "Incineration - Multiple Hearth Furnace", Water & Sewage Works, 114, 307, 1967.

49. Riddell, MD.R. & Cormack, J.W. "Selection of Disposal Methods for Wastewater Treatment Plants", Proc. 10th San. Eng. Conf., University of Illinois Bulletin 65, 115, 131, 1968.

50. "Biological Waste Treatment", Lecture Notes from Course given at Manhattan College, New York, N.U., 1970.

51. Barth, E.F. & Ettinger, M.B., "Mineral Controlled Phosphorus Removal in the Activated Sludge Process", J.W.P.C.F., August 1967.

52. "Nutrient - Phytoplankton Relationships in Eight Southern Ontario Lakes", OWRC Research Publication No. 32.

53. Kuentzel, L.E., "Bacteria, Carbon Dioxide & Algal Blooms", J.W.P.C.F., October 1969.

55. Fair, G.M., Geyer, J.C. & Okun, D.A., "Water & Wastewater Engineering", J. Wiley & Sons, Inc., New York - London, 1966.

56. Zeng, D.R. & Pivnicka, J.R., "Effect of Phosphorus Removal by the Addition of Alum to the Activated Sludge Process", Proced. 24th Industrial Waste Conference, University of Purdue, May 1969.

57. Terry, R.D. & Salback, S.E., "Land Use - Nutrient Level Relationships on Two Southern Ontario Watersheds", Proced. 5th Annual Can. Symposium on Water Pollution Research, 1970.

58. Balakishman, S., Williamson, D.E. & Okey, R.W., "State of the Art Review on Sludge Incineration Practice", Water Pollution Control Research Series 17070 DIV04/70, 1970.

59. Goldstein J., "Transporting Wastes to Build Soils" Compost Science, Sept. - Oct., 1970.

60. Schatz, A., Shatz, V., "Soil Organic Matter as Natural Chelating Material", Compost Science Sept. - Oct., 1970.

61. Conn, R.L. "Liquid Sludge as a Farm Fertilizer", Compost Science, May - June, 1970.

62. McKenna M.F., Clark J.H., "The Economics of Storing, Handling and Spreading of Liquid Hog Manure for Confined Feeder Hog Enterprises", Cornell University Conference on Agricultural Waste Management entitled Relationship of Agriculture to soil and water pollution", 1970.

63. "Sludge Dewatering", W.P.C.F. Manual of Practise No. 20 (1969).

64. Ewing, B.B., Dick R.I., "Disposal of Sludge on Land", In "Water Quality Improvement by Physical & Chemical Processes", E.F. Gloyna and W.W. Eckenfelder Jr., University of Texas Press, 1970.

65. "Land Disposal", Water and Pollution Control August, 1971.

7. APPENDIX

Typical Sludge Hauling Contract (OWRC Operated Plants

(a) Direction to Haul

Within a period of one week of receiving notification of acceptance of his tender, the sludge hauling contractor shall be prepared to commence his regular loading and hauling of the volume of sludge designated by the Director of Plant Operations.

During the duration of the term of sludge hauling, as set out in the purchase order, the contractor shall be required, within 24 hours of receiving verbal or written notice, to load and haul sludge as directed by the Director of Plant Operations or his agent.

(b) Rate of Sludge Production

Notwithstanding any statements or estimates of sludge production made by OWRC staff, the Commission does not warrant or guarantee in any way the maximum or minimum rate of sludge production.

(c) Haulage Rate

The sludge hauling contractor must haul at such a rate that the maximum permissible volume of sludge in storage at the plant as determined by the Director of Plant Operations or his agent is not exceeded.

(d) Invoicing

Invoices, based on a daily log or tally of each load initialled by the plant operator, are to be submitted monthly.

(e) Hold-back and Commission Use of Hold-back

Payment of invoices may be held back until the receipt of the following month's invoice. If the contractor fails to perform under any of these terms, the Director of Plant Operations may order the work done by others and deduct any payment for the increased cost of doing so from this hold-back.

(f) Truck Loading

Trucks must be loaded during regular working hours of the plant staff. The contractor is responsible for the operation of the sludge loading equipment and for any damage done by him to it other than normal wear.

(g) Ownership of Sludge

The sludge shall become the property of the contractor when it is placed in his truck.

(h) Spillage

Spillages in other than regular dumping areas must be cleansed forthwith by the contractor to the satisfaction of the person or body having jurisdiction.

(i) Condition of Trucks

The condition of the equipment to be employed for sludge removal requires the approval of the Director of Plant Operations or his agent. Trucks must be kept clean and in good mechanical condition. The tank or body shall be water tight.

(j) Location and Approval of Disposal Areas

The following factors constitute the necessary requirements relating to the location and approval of disposal areas.

(i) The contractor must make his own arrangements for the disposal areas.

(ii) These arrangements must meet with the requirements of the Medical Officer of Health, the Municipality or any other group having authority and the Director of Plant Operations or his agent must be advised of such approval(s).

(iii) The contractor must obtain written approval of the disposal areas from the Director of Plant Operations or his agent.

(iv) The Director of Plant Operations or his agent reserves the right to determine the routes the contractor may take from the water pollution control plant to the disposal areas should the existing routes provie to be a nuisance to residents along the routes.

(v) The disposal of sludge on areas which have not received written approval from the Director of Plant Operations or his agent may constitute a reason to immediately terminate the sludge disposal contract at the sole discretion of the Director of Plant Operations.

(k) Disposal of Sludge

Sludge may not be dumped from a stationary vehicle unless written approval is obtained from the Director of Plant Operations or his agent.

(l) Submission of Tenders

Written tenders must be received by the OWRC Purchasing Officer prior to 12:00 noon Toronto time on the day specified. The price must be expressed per cubic yard of sludge hauled and the capacity of the vehicles intended for use in the contract must be given in cubic yards on the form provided. The successful bidder will be required to provide satisfactory proof of the tank capacity of his haulage trucks.

(m) The sludge hauling contractor will provide, on request, evidence of General Liability insurance having a limit of not less than $100,000.00 inclusive and automobile liability insurance having a limit of not less than $100,000.00 inclusive.

(n) This contract may be terminated at any time by the Director of Plant Operations at his sole discretion by giving 30 days written notice thereof addressed to the sludge hauling contractor.

TABLE IV: DETAILS OF SITES FOR SLUDGE DISPOSAL BY DUMPING (1970)

Plant	Sludge Treat. prior to disposal	Disposal by	Method of transp.	No. of sites in use	Approx. transp. Dist. (1 way)	Type of site	Site owner-ship	Others using site	REMARKS
PRIMARY TREATMENT PLANTS									
Belleville	an. dig.	Contr.	Tank truck	1	5. mi.	Natural lagoon	Contr.	No	Dumping used as a temporary expedient during wet weather
Cornwall	an. dig.	Contr.	Tank truck	1	7. mi.	Constr. lagoon	Private individ-ual.	No	
Espanola	an. dig.	Contr.	Tank truck	-	5. mi.	Constr. lagoon	Private individ-ual.	No	
Ft. Erie	an. dig.	Contr.	Tank truck	1	5. mi.	San. land fill	Town of Ft.Erie	Yes	
Ft.Frances	an. dig.	Contr.	Tank truck	1	3. mi.	Open dump	Town of Ft.Frances	Yes	
Point Edward	an. dig.	Contr.	Tank truck	1	5. mi.	Constr. lagoons	City of Sarnia	Yes	Lagoons are used by Sarnia for its own sludge disposal.
Port Dover	Vac. filt. Raw sl.	plant staff	Open truck	1	-	Sanit. land fill	Town of Pt. Dover	Yes	

TABLE IV:

Plant	Sludge Treat. prior to disposal	Disposal by	Method of transp.	No. of sites in use	Approx. transp. Dist. (1 way)	Type of site	Site owner-ship	Others using site	REMARKS
Preston	None or vac.filter raw sl.	Contr.	Tank truck or open truck	1	-	Sanit. land fill	Town of Preston	Yes	Dumping used as a temporary expedient during wet weather
S.S.Marie	Vac.filt. raw sl.	Contr.	Open truck	1	13.mi.	Sanit. land fill	Pri. indiv.	Yes	
Thunder Bay (N)	An. dig.	Contr.	Tank truck	1	8. mi.	aband. quarry	Contr.	No	
Thunder Bay (S)	An. dig.	Contr.	Tank truck	1	8. mi.	aband. quarry	Contr.	No	
Timmins	An. dig.	Contr.	Tank truck	1	5. mi.	Sanit. land fill	Town of Timmins	Yes	
Trenton	An. dig.	Trenton Works Dept.	Tank truck	1	1000'	Sanit. land fill	Town of Trenton	Yes	
CONVENTIONAL ACTIVATED SLUDGE PLANTS									
Coniston	An. dig.	Contr.	Tank truck	1	1 mi.	Open dump	Town of Coniston	Yes	
Huntsville	An. dig.	Contr.	Tank truck	2	3 mi.& 6 mi.	Aband. gravel pits.	Private indiv.	No	

TABLE IV:

Plant	Sludge Treat. prior to disposal	Disposal by	Method of transp.	No. of sites in use	Approx. transp. Dist. (1 way)	Type of site	Site owner-ship	Others using site	REMARKS
Kingston Twp.	An. dig.	Contr.	Tank truck	1	8 mi.	Aband. dump	Twp. of Kingston	No	
North Bay	An. dig.	Contr.	Tank truck	1	8. mi.	Aband. quarry	Private individ-ual	No	Use land application for 6 mon.
Sidney Twp.	An. dig.	Contr.	Tank truck	1	10 mi.	Natural lagoon	Contr.	Yes	Same site used for Belleville
S. Peel (all plants except Clarkson)	an. dig.	contr.	tank truck	2	-	aband. gravel pit and constr. lagoon	private no indiv.		One contractor disposes of sludge from all plants (Brampton C., Lakeview, Streetsville, Malton, Erindale, Brampton, Clarkson, Dixie). Dumping used as a temporary expedient during wet weather.
Extended Aeration Plants									
Moosonee	aer. dig.	plant staff	barrel on truck	1	½ mi.	open dump	Town of Moosonee	yes	
Moore Twp.	aer. dig.	contr.	tank truck	1	5 mi.	constr. lagoons	City of Sarnia	yes	Lagoons are used by Sarnia for its own sludge disposal.
Paris	none	contr.	tank truck	1	5 mi.	san. landfill	Town of Paris	yes	
Trickling Filter Plant									
Frankford	none	Town works Dept.	tank truck	-	3 mi.	field	private	no indiv.	

TABLE V DETAILS OF SITES FOR SLUDGE DISPOSAL BY LAND APPLICATION (1970)

PLANT	SLUDGE TREAT. PRIOR TO DISPOSAL	DISPOSAL BY	METHOD OF TRANSP.	APPROX. NO. OF SITES IN USE	APPROX. TOTAL ACREAGE	APPROX. TRANSP. DIST. (1 WAY)	LAND USE	LAND OWNERSHIP	METHOD OF APPLICATION	REMARKS
PRIMARY TREATMENT PLANTS										
BELLEVILLE	AN. DIG.	CONTR.	TANK TRUCK	1	-	5 MI.	-	CONTR.	TANK TRUCK	USE DUMPING ALSO
MIDLAND	AN. DIG.	CONTR.	TANK TRUCK	1	10	3 MI.	PASTURE	PRIVATE INDIV.	TANK TRUCK	
OWEN SOUND	AN. DIG.	CONTR.	TANK TRUCK	4	500	3 TO 8 MI.	PASTURE & CROP	PRIVATE INDIV.	TANK TRUCK, MANURE SPR.	
CONVENTIONAL ACTIVATED SLUDGE PLANTS										
BRANTFORD	AN. DIG.	PLANT STAFF	TANK TRUCK	1	70	3/4 MI.	SOME CORN MOST GRASS	CITY OF BRANTFORD	TANK TRUCK	
BURLINGTON (D.L.)	AN. DIG.	CONTR.	TANK TRUCK	1	150	4 MI.	CROP & PASTURE	CONTR. & PRIVATE INDIV.	TANK TRUCK	SITE USED BY OTHER 2 BURLINGTON PLANTS AND WATERDOWN
BURLINGTON (E.G.)	AN. DIG.	CONTR.	TANK TRUCK	1	150	3 MI.	CROP & PASTURE	CONTR. & PRIVATE INDIV.	TANK TRUCK	AS ABOVE.
CHATHAM	AN. DIG.	CONTR.	TANK TRUCK	1	50	10 MI.	-	PRIVATE INDIV.	TANK TRUCK	
ELMIRA	NONE	CONTR.	TANK TRUCK	2	-	-	CROP (CORN)	PRIVATE INDIV.	TANK TRUCK	
FERGUS	AN. DIG.	CONTR.	TANK TRUCK	1	80	2 MI.	PASTURE & CROP	PRIVATE INDIV.	TANK TRUCK	
GALT	AN. DIG.	CONTR.	TANK TRUCK	1	-	-	CROP	PRIVATE INDIV.	TANK TRUCK	
GEORGETOWN	AN. DIG.	CONTR.	TANK TRUCK	1	40	-	-	PRIVATE INDIV.	TANK TRUCK	
KITCHENER	AN. DIG.	CONTR.	TANK TRUCK	10	-	-	CROP	PRIVATE INDIV.	TANK TRUCK	

PLANT	SLUDGE TREAT. PRIOR TO DISPOSAL	DISPOSAL BY	METHOD OF TRANSP.	APPROX. NO. OF SITES IN USE	APPROX. TOTAL ACREAGE	APPROX. TRANSP. DIST. (1 WAY)	LAND USE	LAND OWNER-SHIP	METHOD OF APPLICA-TION	REMARKS
MARKHAM	AN. DIG.	CONTR.	TANK TRUCK	4 (APPROX.)	-	-	-	PRIVATE INDIV.	TANK TRUCK	
NEWMARKET	AN. DIG.	CONTR.	TANK TRUCK	1	50	2 MI.	-	CONTR.	TANK TRUCK	
NORTH BAY	AN. DIG.	CONTR.	TANK TRUCK	1	75	8 MI.	-	PRIVATE INDIV.	TANK TRUCK	USE DUMPING FOR REMAINDER OF YR.
ORANGEVILLE	AN. DIG.	CONTR.	TANK TRUCK	2	200	5 MI.	PASTURE & CROP (HAY)	PRIVATE INDIV.	TANK TRUCK	
PICKERING	AN. DIG.	CONTR.	TANK TRUCK	1	100	2 MI.	CROP (ORCHARD)	PRIVATE INDIV.	TANK TRUCK	
PORT COLBORNE(E)	AN. DIG.	CONTR.	TANK TRUCK	2	120	2 MI.	CROP	PRIVATE INDIV. & MUNICI-PALITY	TANK TRUCK	
PORT COLBORNE(W)	AN. DIG.	CONTR.	TANK TRUCK	2	120	2 MI.	CROP	PRIVATE INDIV. & MUNICI-PALITY	TANK TRUCK	
PRESTON	NONE, VAC. FILT.	CONTR.	TANK TRUCK, OPEN TRUCK	7	-	-	CROP	PRIVATE INDIV.	TANK TRUCK & MANURE SPREAD-ER	
RICHMOND HILL	AN. DIG.	CONTR.	TANK TRUCK	1	50	2 MI.	CROP	PRIVATE INDIV.	TANK TRUCK	
SIMCOE	AN. DIG. & CENTRIFUGE	CONTR.	TANK TRUCK	-	-	-	-	PRIVATE INDIV.	TANK TRUCK	LAND APPLICATION USED SPARINGLY. MOST SLUDGE GOES TO DRYING BEDS.
SOUTH PEEL (ALL B PLANTS)	AN. DIG.	CONTR.	TANK TRUCK	7	1500	-	CROP & PASTURE	PRIVATE INDIV.	TANK TRUCK	ONE CONTRACTOR DIS-POSES OF SLUDGE FROM ALL B PLANTS. (BRAMPTON, MALTON, ERINDALE, BRAMPTON, CLARKSON, DIXIE) DUMPING USED AS A TEMPORARY EXPEDIENT DURING WET WEATHER.

PLANT	SLUDGE TREAT. PRIOR TO DISPOSAL	DISPOSAL BY	METHOD OF TRANSP.	APPROX. NO. OF SITES IN USE	APPROX. TOTAL ACREAGE	APPROX. TRANSP. DIST. (1 WAY)	LAND USE	LAND OWNER-SHIP	METHOD OF APPLICA-TION	REMARKS
STRATFORD	AN. DIG.	CONTR.	TANK TRUCK	4	-	-	CROP	PRIVATE INDIV.	TANK TRUCK	
TILLSONBURG	AN. DIG.	CONTR.	TANK TRUCK	5	100	3 MI.	CROP & PASTURE	PRIVATE INDIV.	TANK TRUCK	
WATERDOWN	AN. DIG.	CONTR.	TANK TRUCK	>1	150	7 MI.	CROP & PASTURE	CONTR.& PRIV. INDIV.	TANK TRUCK	SITES USED BY THE 3 BURLINGTON PLANTS ALSO
WATERLOO	AN. DIG.	CONTR.	TANK TRUCK	12	-	-	CROP	PRIVATE INDIV.	TANK TRUCK	
EXTENDED AERATION PLANTS										
BURLINGTON (SKY.)	NONE	CONTR.	TANK TRUCK	>1	150	4½ MI.	CROP & PASTURE	CONTR. PRIVATE INDIV.	TANK TRUCK	SITES USED BY OTHER 2 BURLINGTON PLANTS & WATERDOWN
ELORA	NONE	PLANT STAFF	PUMP & HOSE	1	1	0	PLANT LAWN	OWRC	HOSE	
WESTMINSTER TOWNSHIP	AER. DIG.	CONTR.	TANK TRUCK	-	-	2MI.	CROP (CORN, GRAIN)	PRIVATE INDIV.	TANK TRUCK	

TABLE VI - SLUDGE DISPOSAL COSTS FOR OWRC OPERATING PLANTS

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry Solids
PRIMARY PLANTS									
BELLEVILLE	1967	6.57	An. dig.	5048	9.9	Dumping & land application	3020	.600	6.90
	1968	5.90	An. dig.	1460	8.1	Dumping & land application	876	.600	8.51
	1969	5.30	An. dig.	2927	6.4	Dumping & land application	1760	.600	10.90
CORNWALL	1967	- (1)	None	-	-	None	-	-	-
	1968	-	None	-	-	None	-	-	-
	1969	6.90	An. dig.	1764 (2)	12.5	Dumping	2460	1.50	13.5
ESPANOLA	1967	-	An.dig.	154	-	Dumping	246	1.60	-
	1968	-	An. dig.	154	-	Dumping	246	1.60	-
	1969	.09	An. dig.	99	-	Dumping	159	1.60	-
FORT ERIE	1967	1.70	An.dig.	451	10.3	Dumping	384	.850	9.35
	1968	1.44	An. dig.	996	7.3	Dumping	846	.850	13.4
	1969	1.63	An. dig.	630	6.8	Dumping	536	.850	14.5
FORT FRANCES	1967	1.89	An. dig.	534	6.4	Dumping	1500	2.80	51.0
	1968	2.00	An. dig.	578	5.5	Dumping	1620	2.80	59.9
	1969	1.90	An. dig.	1052	8.0	Dumping	2950	2.80	40.3
MIDLAND	1967	1.32	An. dig.	1422	5.8	Land application	1710	1.20	24.2
	1968	1.36	An. dig.	2003	11.9	Land application	2440	1.22	11.6
	1969	1.30	An. dig.	2970	10.4	Land application	3830	1.29	14.1

NOTE: (1) Plant put into service January 1969

(2) Sludge hauled for 4 months only

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
OWEN SOUND	1967	3.88	An. dig.	9821	7.9	Land application	9510	.970	14.2
	1968	4.00	An. dig.	6232	4.9	Land application	6040	.970	23.3
	1969	4.00	An. dig.	8875	8.5	Land application	8600	.970	13.1
PARRY SOUND	1967	.64	An. dig. dry bed	-	-	- (1)	-	-	-
	1968	.54	An. dig. dry bed	449	-	-	450	.970	-
	1969	.70	An. dig. dry bed	445	-	-	436	.970	-
POINT EDWARD	1967	.21	An. dig.	233	4.9	Land application	279	1.20	28.8
	1968	.28	An. dig.	173	5.5	Land application	246	1.42	30.2
	1969	.21	An. dig.	384	6.7	Land application	688	1.79	31.0
PORT DOVER	1967	.31	Vac. filter	270	-	Dumping (2)	-	-	-
	1968	.34	Vac. filter	453	-	Dumping	-	-	-
	1969	.36	Vac. filter	379	25.0	Dumping	-	-	-
SAULT STE. MARIE	1967	7.66	Vac. filter	7126	-	Dumping	11400	1.60	-
	1968	8.70	Vac. filter	6811	-	Dumping	10900	1.60	-
	1969	8.70	Vac. filter	7526	27.0	Dumping	11300	1.50	5.85
THUNDER BAY(N)	1967	4.97	An. dig.	8384	-	Dumping	6790	.81	-
	1968	5.34	An. dig.	7770	6.6	Dumping	6430	.828	14.6
	1969	4.70	An. dig.	6032	7.0	Dumping	4810	.796	13.2

NOTES: (1) Removed from drying beds by private individuals

(2) Disposal by plant staff

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
THUNDER BAY(S)	1967	3.95	An. dig.	3362	-	Dumping	3030	.900	-
	1968	5.70	An. dig.	4162	12.8	Dumping	3750	.900	7.83
	1969	4.90	An. dig.	2214	15.5	Dumping	1860	.838	5.95
TIMMINS	1967	3.14	An. dig.(1)	8326	4.8	Dumping	11000	1.32	32.3
	1968	2.93	An. dig.	11575	4.3	Dumping	13700	1.19	32.7
	1969	2.90	An. dig.	13562	5.2	Dumping	13600	1.00	22.6
TRENTON	1967	1.11	An. dig.	672	11.1	Dumping (2)	-	-	-
	1968	1.27	An. dig.	611	9.4	Dumping	-	-	-
	1969	2.10	An. dig.	702	11.3	Dumping	-	-	-

NOTES: (1) Sludge hauled during 9 months only

(2) Disposal by Trenton Works Department

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
CONVENTIONAL ACTIVATED SLUDGE PLANTS									
BRANTFORD	1967	7.18	An. dig. & Vac. filter	15003	18.9	Land application	5560	.370	2.14
	1968	7.22	An. dig. & Vac. filter	16668	18.0	Land application	5710	.344	2.10
	1969	7.60	An. dig. & Vac. filter	9651	19.0	Land application	3420	.354	2.19
			An. dig. & Vac. filter	33914 (1)	4.5	Land application	12400	.376	9.85
BURLINGTON (D.L.)	1967	1.63	An. dig.	9167	4.7	Land application	5040	.550	13.8
	1968	1.92	An. dig.	6058	5.5	Land application	4670	.770	16.4
	1969	1.60	An. dig.	4868	5.7	Land application	5210	1.07	22.0
BURLINGTON (E.G.)	1967	1.05	An. dig.	2702	4.0	Land application	1490	.550	16.2
	1968	1.06	An. dig.	3869	3.5	Land application	2987	.773	26.1
	1969	1.10	An. dig.	6152	2.7	Land application	6631	1.08	47.6
CHATHAM	1967	3.15	An. dig.	14683	6.0	Land application	9400	.640	12.5
	1968	3.80	An. dig.	18893	5.1	Land application	12000	.633	14.6
			An. dig. & dry bed	- (2)	-	-	-	-	-
	1969	4.10	An. dig.	13872	5.2	Land application	8590	.620	14.0
			An. dig. & dry bed	- (3)	-	-	-	-	-

NOTES: (1) Disposal by plant staff

(2) 11.8% of an. dig. sludge pumped to dry bed

(3) 36.5% of an. dig. sludge pumped to dry bed

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds.)	T.S.(%)		Total $	$/cu. yd.	$/Ton dry solids
CONISTON	1967	.19	An. dig. & dry bed	-	-	Dumping	-	-	-
	1968	.20	An. dig. & dry bed	355	-	Dumping	-	-	-
	1969	.19	An. dig. & dry bed	228	-	Dumping	-	-	-
			An. dig.	274	-	Dumping	-	-	-
ELMIRA	1967	.70	None	60	0.5	Land application	60	1.00	238.
	1968	.70	None	2721	-	Land application	2721	1.00	-
	1969	.53	None	484	-	Land application	484	1.00	-
FERGUS	1967	.71	An. dig.	2649	3.3	Land application	2790	1.05	37.7
	1968	.63	An. dig.	3210	-	Land application	3370	1.05	-
	1969	.60	An. dig.	4875	3.0	Land application	4900	1.05	39.5
GALT	1967	5.70	An. dig.	-	3.8	Land application	-	.920	28.7
			An. dig. & Vac. filter	4003	25.1	Land application	3680	.920	3.86
	1968	5.87	An. dig.	12488	4.0	Land application	13700	1.10	32.6
			An. dig. & Vac. filter	94	25.0	Land application	103	1.10	4.62
	1969	6.00	An. dig.	12012	4.2	Land application	11100	.850	23.9
GEORGETOWN	1967	1.78	None (1)	8650	9.1	Land application	8930	1.03	13.0
	1968	1.47	None (1)	7425	8.1	Land application	7790	1.05	14.9
	1969	1.32	None (1)	9981	7.7	Land application	10700	1.07	15.9
HUNTSVILLE	1967	.23	An. dig.	466	5.0	Dumping	396	.850	20.0
	1968	.26	An. dig.	1540	3.4	Dumping	1310	.850	29.6
	1969	.29	An. dig.	1893	3.7	Dumping	1695	.895	28.6

NOTES: (1) Digester malfunctioning

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S.(%)		Total $	$/cu. yd.	$/ton dry solids
KINGSTON TWP.	1967	.71	An. dig.	-	5.2	-	-	-	-
	1968	.86	An. dig.	-	4.1	-	-	-	-
	1969	.90	An. dig.	1192	4.4	Dumping	1416	1.19	32.1
KITCHENER	1967	10.14	An. dig.	40200 (1)	6.0	Land application	39200	.970	18.9
			An. dig. & Vac. filter	19449	24.2	Land application	17900	.920	4.05
	1968	9.96	An. dig.	84855 (2)	3.9	Land application	82200	.970	29.5
			An. dig. & Vac. filter	1079	22.0	Land application	990	.920	4.51
	1969	10.70	An. dig.	55748 (2)	3.6	Land application	44600	.800	26.3
MARKHAM	1967	.62	An. dig.	-	3.2	Land application	-	-	-
	1968	.55	An. dig.	238	5.9	Land application	257	1.18	23.4
			An. dig. & dry bed	- (3)	-	- (4)	0	0	0
	1969	.59	An. dig.	2320	4.3	Land application	2320	1.18	32.5
			An. dig. & dry bed	18	-	- (4)	0	0	0
NEPEAN TWP.	1967	2.81	An. dig.&dry.lag.	- (5)	-	None	0	0	0
	1968	2.10	An. dig.&dry.lag.	- (5)	-	None	0	0	0
	1969	2.10	An. dig.&dry.lag.	- (5)	-	None	0	0	0

NOTES: (1) Value is approximate.
(2) In 1968 & 1969, 4.7% and 44.9% of digested sludge respectively went to drying lagoons and has not been disposed of yet.
(3) 78% of digested sludge went to drying bed.
(4) Removed from drying beds by private individuals.
(5) 100% of digested sludge went to drying lagoons and has not been disposed of yet.

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S.(%)		Total $	$/cu. yd.	$/Ton dry solids
NEWMARKET	1967	1.66	An. dig.	5482	5.1	Land application	4930	.900	20.7
	1968	1.45	An. dig.	5682	4.9	Land application	5120	.900	21.6
	1969	1.70	An. dig.	7164	5.5	Land application	6450	.900	19.2
NORTH BAY	1967	3.94	An. dig.	17588	4.0	Land application & dumping	10350	.590	17.5
	1968	4.22	An. dig.	20788	4.0	Land application & dumping	12200	.590	17.5
	1969	4.90	An. dig.	27051	6.7	Land application & dumping	18610	.690	11.9
ORANGEVILLE	1967	.66	None (1)	658	-	Land application	986	1.50	-
	1968	.63	None	1608	-	Land application	2417	1.50	-
	1969	.70	An. dig.	1482	4.7	Land application	2220	1.50	37.5
PICKERING	1967(2)	0	None	0					
	1968	0	None						
	1969	.10	An. dig.						
PORT COLBORNE (E)	1967	1.13	An. dig.	1899	2.2	Land application	1100	.580	31.4
	1968	1.37	An. dig.	1324	-	Land application	768	.580	-
	1969	1.50	An. dig.	895	3.9	Land application	519	.618	18.7
			None	332	-	Land application	193	.580	-
PORT COLBORNE (W)	1967	1.06	An. dig.	1781	2.1	Land application	1030	.580	32.8
	1968	1.20	An. dig.	2291	2.5	Land application	1330	.580	27.6
	1969	1.10	An. dig.	2709	2.9	Land application	1600	.590	24.2
			An. dig. & dry bed	80	-	-	-	-	-

NOTES: (1) Digester put into service November, 1968

(2) Plant put into service April, 1969

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S.(%)		Total $	$/cu. yd.	$/Ton dry solids
PRESTON	1967	1.15	None	1755	8.0	Land application & dumping (1)	1580	.900	12.8
			Vac. filter	2840	21.2	Land application & dumping	2620	.920	4.69
	1968	1.49	None	5762	9.4	Land application & dumping	5440	.945	11.3
			Vac. filter	4762	24.0	Land application & dumping	7860	1.65	7.26
	1969	1.30	None	5797	8.4	Land application & dumping	5510	.950	12.8
			Vac. filter	5160	22.0	Land application & dumping	8520	1.65	8.08
RICHMOND HILL	1967	1.82	An. dig.	13948	2.9	Land application	12200	.875	35.8
	1968	1.93	An. dig.	14436	2.9	Land application	12600	.870	35.6
	1969	2.10	An. dig.	14758	4.7	Land application	12900	.870	21.8
SIDNEY TWP.	1967	.22	An. dig.	161	3.7	Dumping	188	1.17	37.4
	1968	.25	An. dig.	0	0	Dumping	0	0	0
	1969	.32	An. dig.	168	4.4	Dumping	168	1.00	26.8
SIMCOE	1967	1.70	An. dig. & dry bed	0		None (2)			
	1968	1.80	An. dig. & dry bed	0		None (2)			
	1969	1.70	An. dig. & dry bed			None (2)			

NOTES: (1) Dumping was a temporary expedient during wet weather.

(2) All sludge went to drying beds and hasn't been removed yet.

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
SOUTH PEEL a) Brampton (Ching.)	1967	3.80	An. dig.	18100 (2)	3.6	Land application	18100	1.00	32.9
			An. dig. & Vac. filter	242	-	Land application	-	-	-
	1968	3.60	An. dig.	31110	3.7	Land application	31100	1.00	32.0
			An. dig. & Vac. filter	31	-	Land application	-	-	-
	1969	4.12	An. dig.	35294	2.4	Land application & dumping (2)	46400	1.31	64.6
b) Lakeview	1967	9.85	An. dig.	50863	6.2	Land application & dumping	50900	1.00	18.8
			An. dig. & dry lag.	- (1)	-	Land application & dumping	-	-	-
	1968	11.66	An. dig.	86080	5.9	Land application & dumping	99600	1.16	23.0
			An. dig. & dry lag.	771	-	Land application & dumping	-	-	-
	1969	12.53	An. dig.	114180	5.2	Land application & dumping	138000	1.21	27.4
c) Streetsville	1967	.66	An. dig.	2040	-	Land application	2040	1.00	-
			An. dig. & dry lag.	83	-	Land application	-	-	-
	1968	.59	An. dig.	2781	-	Land application	3070	1.10	-
			An. dig. & dry lag.	46	-	Land application	-	-	-
	1969	.74	An. dig.	4717	-	Land application & dumping (2)	5640	1.20	-

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S.(%)		Total $	$/cu. yd.	$/Ton dry solids
d) Malton	1967	- (3)	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-
	1969	-	An. dig.	-	-	Land application & dumping (2)	-	1.25	-
e) Erindale	1967	- (3)	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-
	1969	-	An. dig.	-	-	Land application & dumping (2)	-	1.30	-
f) Brampton (Town)	1967	- (3)	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-
	1969	-	An. dig.	-	-	Land application & dumping (2)	-	1.60	-

NOTES: (1) 8.2% of digested sludge went to drying bed.

(2) Dumping was a temporary expedient during wet weather.

(3) Plant not operated by OWRC until July, 1969.

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
g) Clarkson	1967	- (1)	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-
	1969	-	An. dig.	-	-	Land application	-	1.65	-
h) Dixie	1967	- (1)	-	-	-	-	-	-	-
	1968	-	-	-	-	-	-	-	-
	1969	-	An. dig.	-	-	Land application & dumping (2)	-	1.70	-
STRATFORD	1967	4.35	An. dig.	14983	4.2	Land application	9150	.611	17.2
	1968	3.40	An. dig.	15339	4.7	Land application	9970	.650	16.3
	1969	3.60	An. dig.	13977	6.1	Land application	9850	.706	13.6
TILLSONBURG	1967	.76	An. dig.	5432	2.3	Land application	5280	.972	50.3
	1968	.72	An. dig.	5186	2.5	Land application	4670	.900	42.8
	1969	.59	An. dig.	3518	2.5	Land application	3230	.920	43.8
WATERDOWN	1967	.06	An. dig.	-	-	Land application	-	-	-
	1968	.05	An. dig.	741	3.0	Land application	668	.900	35.5
	1969	.06	An. dig.	782	2.5	Land application	1142	1.46	69.1
WATERLOO	1967	3.99	An. dig.	12735	-	Land application	11679	.918	-
			An. dig. & Vac. filter	8504	17.2	Land application	7810	.920	5.89
	1968	4.31	An. dig.	16766	-	Land application	15100	.900	-
			An. dig. & Vac. filter	6431	17.0	Land application	9650	1.50	9.60
	1969	5.00	An. dig.	35654	3.4	Land application	30500	.865	30.1

NOTES: (1) Plant not operated by OWRC until July, 1969.

(2) Dumping was a temporary expedient during wet weather.

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yds)	T. S. (%)		Total $	$/cu. yd.	$/Ton dry solids
EXTENDED AERATION PLANTS									
BURLINGTON (SKY.)	1967	3.89	None (1)	6960	-	Land application	3830	.550	-
	1968	3.70	None	7983	-	Land application	6290	.787	-
	1969	3.30	None	7459	-	Land application	7290	.978	-
ELORA	1967	.06	None (1)	-	-	Land application (2)	-	-	-
	1968	.19	None	-	-	Land application	-	-	-
	1969	.07	None	-	-	Land application	-	-	-
MOORE TWP.	1967	.12	Aer. dig.	234	-	Land application	325	1.39	-
	1968	.20	Aer. dig.	416	-	Land application	612	1.47	-
	1969	.12	Aer. dig.	858	-	Land application	1568	1.83	-
MOOSONEE	1967	-	Aer. dig. (3)	0		None			
	1968	-	Aer. dig.	0		None			
	1969	.04	Aer. dig.	0		Dumping			
PARIS	1967	-	None (1)	-	-	Dumping	-	-	-
	1968	.43	None	-	-	Dumping	-	-	-
	1969	.26	None	-	-	Dumping	-	-	-
WESTMINSTER TWP.	1967	.24	None	-	-	Land application	-	-	-
	1968	.55	None	-	-	Land application	-	-	-
	1969	.35	None	-	-	Land application	-	-	-

NOTES: (1) Waste activated sludge.
(2) Disposal by plant staff.
(3) Plant put into service July, 1968.

PLANT	YEAR	SEWAGE TREATED (IMGD)	SLUDGE TREATMENT PRIOR TO DISPOSAL	TREATED SLUDGE DISPOSED OF		SLUDGE DISPOSAL METHOD	DISPOSAL COSTS		
				Vol. (cu. yd.)	T.S. (%)		Total $	$/cu. yd.	$/Ton dry solids
OTHER PLANTS									
HAILEYBURY (1)	1967	-	None (2)	0		None			
	1968	-	Aer. dig.	0		None			
	1969	.30	Aer. dig.	0		None			
FRANKFORD (3)	1967	.16	None	-	-	Land application (4)	-	-	-
	1968	.18	None	-	-	Land application (4)	-	-	-
	1969	.14	None	-	-	Land application (4)	-	-	-

NOTES: (1) Contact stabilization process.

(2) Plant put into service September, 1968.

(3) Trickling filter process.

(4) Disposal by Village Works Department.

SEWAGE SLUDGE DISPOSAL

ERRATA

Page 5 and page 6 are interchanged

Page 12 - Insert new page 12 (attached)

Page 17 - TABLE II

- Third from last column should be headed "avg. values (6)" and should include a value of 35 for humus

- Second from last column should be headed "San Diego, Cal. (6)"

- Last column should be headed "Chicago Ill. (3)"

Page 23 ff - Insert Table III (attached)

FIGURE 1.

RELATIONSHIP BETWEEN SLUDGE APPLICATION RATE AND LAND AREA REQUIRED

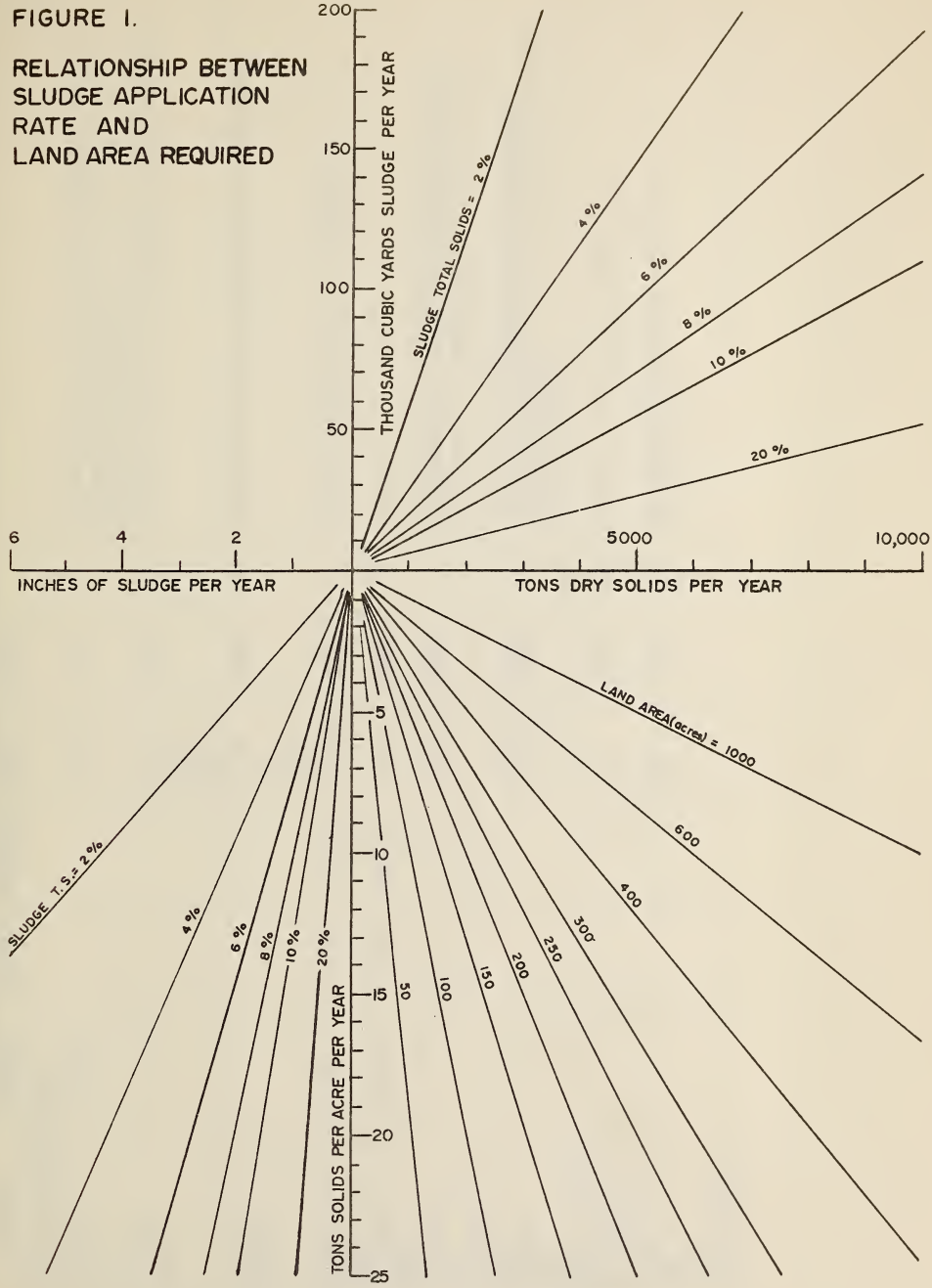


TABLE III (continued)

PLANT LOCATION	POPULATION SERVED	COST (in $/ton dry solids) CAPITAL	OPERATING	TOTAL	PUBL^{n} DATE	REF.	REMARKS
LAND APPLICATION							
Chicago, Ill., *	5.5×10^6			15.00	1968	3	No dewatering; includes an. digestion, transportation by pipeline and spray irrig. system; disposal on farm land.
U.S. in general				4. to 30. (avg. 10)	1968	6	Excludes cost of an. digestion; no dewatering.
U.S. in general				8. to 50. (avg. 15.)	1968	6	Includes cost of an. digestion; no dewatering.
Lynwood, Wash.	8,000	7.50	38.48	45.98	1965	6	Includes single stage an. digestion
Lynwood, Wash.	22,000	7.50	26.80	34.30	1965	6	As above
San Diego Cal.				9.91	1960	6	No dewatering, 6% T.S.; excludes cost of an. digestion & transportation by truck 10.5 mi.
San Diego Cal.				4.00	1960	6	As above but transportation by pipe line.
Orlando Fla.				13.20	1968	3	Cost assumes 6% T.S. in sludge; sludge applied to citrus groves.
Maple Lodge Works, U.K.				24.	1966	50	No dewatering; approx. 4% T.S.
St. Mary's Penn.				20.	1967	50	No dewatering; approx. 4.1% T.S.
Avg. for 9 Penn. communities				13.	1967	50	No dewatering.

TABLE III

PLANT LOCATION	POPULATION SERVED	COST (in $/ton dry solids) CAPITAL	OPERATING	TOTAL	PUBL'N DATE	REF	REMARKS
INCINERATION							
U.S. in general	100,000 500,000 1,000,000 2,000,000			60-90 50-75 30-50 25-40	1970	7.	For incineration at activated sludge plants in general; includes cost of dewatering by vac filtration & administrative overhead;
U.S. in general				10-50 (avg. 30)	1968	6.	For multiple hearth & fluid bed; includes costs of dewatering.
East Cliff Cal.			25.32		1965	6.	For fluid bed; excludes costs of dewatering.
U.S. in general	100,000	11.75	14.27	26.02	1964	6.	For multiple hearth; includes cost of dewatering by vac. filt; excludes costs of ash disposal & costs of deodorization.
	100,000	12.07	17.41	29.48	1964	6.	As above but includes costs of deodorization.
Lynwood, Wash.	8.000	15.00	20.44	35.44	1965	6.	For fluid bed; includes costs of dewatering.
	22,000	15.00	11.38	26.38	1965	6.	As above.
Beaconsfield Quebec *		15-30	15-25	30-55	1961	18.	For atomized suspension technique; includes of sludge thickening tank.
U.S. in general *	1,000,000			8.71	1968	28.	For multiple hearth, includes dewatering by vac. filtration
	10,000			13.90	1968		As above
Minneapolis St. Paul Minnesota			6.34		1967	48.	As above
* estimated costs							
DUMPING							
U.S. in general				10. to 50. (25 avg.)	1968	6	Includes dewatering, disposal at landfill site.
				1. to 5.	1968	6	No dewatering; disposal at landfill site.

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ONTARIO. MIN. OF THE ENVIRONMENT

AROT

SEWAGE SLUDGE DISPOSAL

DATE	ISSUED TO
DEC 12 1975	G.B. Bjorke
~~MAR - 4 1976~~	8328 Holly Lane.
MAR - 4 1976	Suite 204, Ottawa, Ont
	D. Cliffe CAMBRIDGE.

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Ontario Ministry of the En
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